Monitoring report form
(Version 03.2)

Monitoring report

Title of the project activity	N_2O Abatement Project of Capro Corporation
Reference number of the project activity	4665
Version number of the monitoring report	v.4
Completion date of the monitoring report	14/12/2013
Registration date of the project activity	09/06/2011
Monitoring period number and duration of this monitoring period	Period Number 4 Duration : 09/06/2012 – 31/12/2012
Project participant(s)	Capro Corporation Hyosung Ebara Engineering Co., Ltd. Hyosung Corporation
Host Party(ies)	The Republic of Korea
Sectoral scope(s) and applied methodology(ies)	・Sectoral scope Scope No. 5, Chemical industries ・Applied methodology AM0028(Version 05) N2O destruction in the tail gas of Nitric Acid or Caprolactam Production Plants
Estimated amount of GHG emission reductions or net anthropogenic GHG removals by sinks for this monitoring period in the registered PDD	373,054 tCO_2e/period (Year total amount in PDD : 660,995 tCO_2e/y)
Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved in this monitoring period	330,581 tCO_2e

SECTION A. Description of project activity

A.1. Purpose and general description of project activity

>>

(a) Purpose of the project activity and the measures taken for GHG emission reductions;

The proposed project is to reduce N_2O emissions of the tail gas emitted from Caprolactam production process in Capro Corporation (hereinafter "Capro") by installing catalytic N_2O destruction system.

(b) Brief description of the installed technology and equipments;

N_2O treatment system for this project is CRI N_2O abatement system, which is N_2O decomposition catalyst at the tail gas. Therefore, CRI system applies to tertiary treatment, which does not affect the existing yield of caprolactam as it just treats the tail gas. In addition, the catalyst system is remarkably efficient as CRI technology is direct N_2O decomposition process that does not require the addition of any reductant and its pressure drop is small.

(c) Relevant dates for the project activity.

Relevant dates (dd/mm/yyyy)	The Actions for Implementation of Project activity
16/11/2010	Starting Construction of N_2O abatement system
20/04/2011	Commissioning start(Plant 1)
27/04/2011	Commissioning start(Plant 2)
02/05/2011	Completing Construction of N_2O abatement system and the N_2O abatement system started normal operation
23/05/2011 ~27/05/2011	Field Test for Quality Assurance of installation and calibration of AMS (QAL2)
09/06/2011	Registration date of this project, which means the starting date of the crediting period of this project.
26/09/2011 ~29/09/2011	Additional Field Test for Quality Assurance (QAL2) of installation and calibration of AMS
14/05/2012 ~17/05/2012	Annual surveillance test (AST) for Quality Assurance of AMS

(d) Total emission reductions achieved in this monitoring period: 330,581 tonCO_2e

A.2. Location of project activity

>>

(a) Host Parties
: The Republic of Korea

(b) Region/State/Province, etc.
: Ulsan Metropolitan City

(c) City/Town/Community etc.
: 402-1, Bugok-dong, Nam-gu

(d) Physical/ Geographical Location
: The east longitude is about 129.3280 and the north latitude is about 35.4958

A.3. Parties and project participant(s)

Party involved ((host) indicates a host Party)	Private and/or public entity(ies) project participants (as applicable)	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
The Republic of Korea(host)	Private entity •Capro Corporation •Hyosung Ebara Engineering Co., Ltd. •Hyosung Corporation	No

A.4. Reference of applied methodology

>>

(a) The applied methodology :

AM0028 “N2O destruction in the tail gas of Nitric Acid or Caprolactam Production Plants” (Version 05.0)

(b) Any tools to which the applied methodology refers :

“Version 05.2 of the”Tool for the demonstration and assessment of additionality”(Version 05.2)

(c) other methodologies to which the applied methodology refers

: None

The methodology tool are available on the following website:
http://cdm.unfccc.int/methodologies/PAmethodologies/approved

A.5. Crediting period of project activity

>>

The type of Crediting Period			fixed	
The starting date of the crediting period (dd/mm/yyyy)			09/06/2011	
The length of the crediting period			10 years	
Implemented Monitoring period	Year	Period No.		No. of days
	1st year	1st	09/06/2011~ 31/08/2011	84
		2nd	01/09/2011~ 31/12/2011	122
		3rd	01/01/2012~ 08/06/2012	160
		Accumulated no. of operating days for year		**366**
	2nd year	4th (This Period)	09/06/2012 ~31/12/2012	205

SECTION B. Implementation of project activity

B.1. Description of implemented registered project activity

>>

(a) General Introduction

Caprolactam is produced by cyclohexane, ammonia, and sulphur as its primary raw materials, and Ammonium sulfate comes out as a by-product, which is supplied as nitrogen fertilizer and a chemical feedstock for industrial uses. In Capro, the main process of caprolactam production is as follows:

Hydroxylamine sulfate preparation ;

Ammonium carbonate preparation

$$2NH_4OH + CO_2 \rightarrow (NH_4)_2CO_3 + H_2O$$

Ammonia oxidation

$$4NH_3 + 5O_2 \xrightarrow{\text{Pt-Rh catalyst}} 4NO + 6H_2O$$

$$(2NO + O_2 \rightarrow 2NO_2)$$

Ammonium Nitrite Preparation;

$$(NH_4)_2CO_3 + NO + NO_2 \rightarrow 2NH_4NO_2 + CO_2$$

Hydroxylamine disulfonic ammonia Preparation;

$$NH_4NO_2 + NH_4OH + 2SO_2 \rightarrow NOH(SO_3NH_4)_2$$

Hydroxylamine Sulfate Preparation;

$$NOH(SO_3NH_4)_2 + H_2O \rightarrow NHOHSO_3NH_4 + NH_4HSO_4$$

$$2NHOHSO_3NH_4 + 2H_2O \rightarrow (NH_2OH)_2H_2SO_4 \text{ (Hydroxylamine sulfate)} + (NH_4)_2SO_4$$

Cyclohexanone preparation

$$C_6H_{12} \xrightarrow{\text{Co catalyst, } [O_2]} C_6H_{10}O \text{ (Cyclohexanone)}$$

Oximation Reaction;

$$(NH_2OH)_2H_2SO_4 + 2C_6H_{10}O \rightarrow 2C_6H_{10}NOH \text{ (Cyclohexanone oxime)} + H_2SO_4 + H_2O$$

Beckmann rearrangement;

$$C_6H_{10}NOH \xrightarrow{H_2SO_4 \text{ catalyst}} C_6H_{10}NOH \text{ (Caprolactam)}$$

Cyclohexanone oxime reacts with sulfuric acid catalyst to caprolactam as final product. The structural formula of Beckmann rearrangement is shown in Figure B1-1.

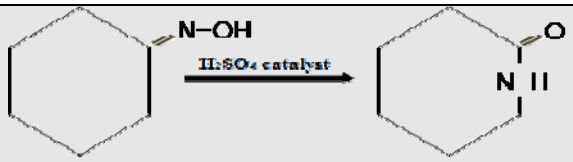

Figure B1-1. Structural formula of Beckmann rearrangement

The block flow diagram for existed caprolactam production process of Capro is shown in Figure B1-2.

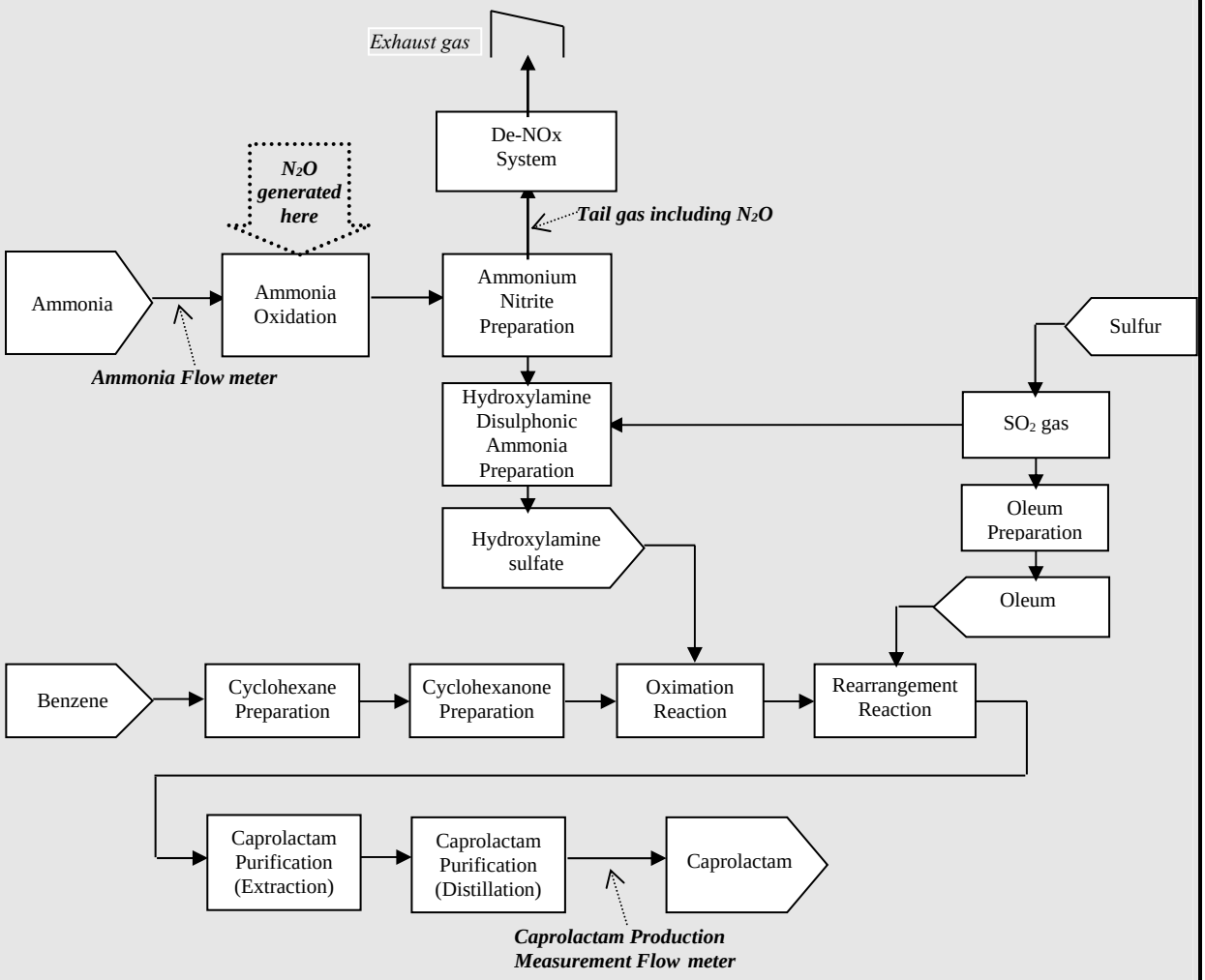

Figure B1-2. Block flow diagram for caprolactam production process

Ammonia oxidation reaction is necessary to generate NO and NO_2, which are going to be the reactants for Ammonium nitrite. (This Ammonium nitrite will induce Hydroxylamine sulphate, and finally caprolactam will be produced, through the complicated reaction pathway, as previous stated at the paragraph to explain the main process of caprolactam production.)

Nitrous oxide (N_2O) is generated as an undesired by-product through the side reaction of Ammonia oxidation as follows:

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$	(Main reaction)
$(2NO + O_2 \rightarrow 2NO_2)$	(Desired in the NO oxidation process)
$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$	(Side reaction)
$4NH_3 + 4O_2 \rightarrow 2N_2O + 6H_2O$	(Side reaction)

In this project, two plants (Plant I, Plant II) are included. In each plant, there are two of the Ammonium Oxidation Reactors (AORs), the ammonia gas is equally fed to the both of AORs through the one line with one flow meter. Input ammonia is oxidized by passing through the Pt-Rh Catalyst gauze located in AOR.

(b) Description of the installed technology, technical processes and equipments;

De-N_2O system for this project is to destruct the N_2O included in tail gas by catalyst without any reducing agent.

$$2N_2O \xrightarrow{\text{Catalyst}} 2N_2 + O_2$$

The catalytic reactor designed by Hyosung Ebara Engineering Co. was derived from RTO (Regenerative Thermal Oxidizer), to save the energy required for catalytic reaction to decompose N_2O, and this N_2O destruction facility is the so-called "Regenerative Catalytic System". Where, liquefied natural gas (LNG, hereafter "natural gas") is put in to this system as a fuel, not reducing agent, to supply the energy required for the de-N_2O catalytic reaction. Catalyst is provided by CRI.

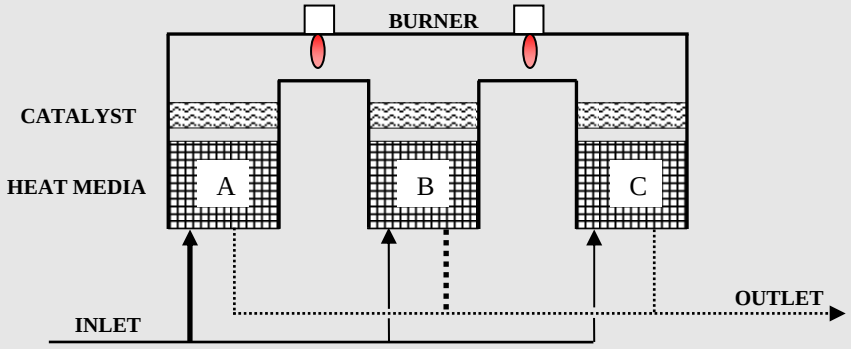

Figure B1-3. Overview of Regenerative Catalytic System

The principle of performance can be step-wisely described with Figure B1-3 as follows: At the inlet of De-N_2O system, in-flowed tail-gas is heated up to 550℃ by going to heat media A(previously heated), before N_2O included in the heated tail is decomposed while that tail gas is pass through catalytic bed located on the top of heat storage media A. And then, N_2O in the once treated tail gas is decomposed again by the next catalyst bed and the heat storage media B, to which the heat hold in two-times-treated tail gas is transfer. After this, two-times-treated tail gas is going out. Next, tail gas is injected in to the heat media B which is charged with heat transferred from the outflow according to the way explain just above. And the tail gas passed through the heat storage media B and the upper catalyst bed is going to the other catalyst bed and the heat media C. Finally, the tail gas from the plant goes to the media C heated by the previous outflow, this tail gas is flowed reversely to the media B and comes out. In this way, tail gas in-and-out is continuously rotated. The same De-N_2O processes have been applied to Plant I and II.

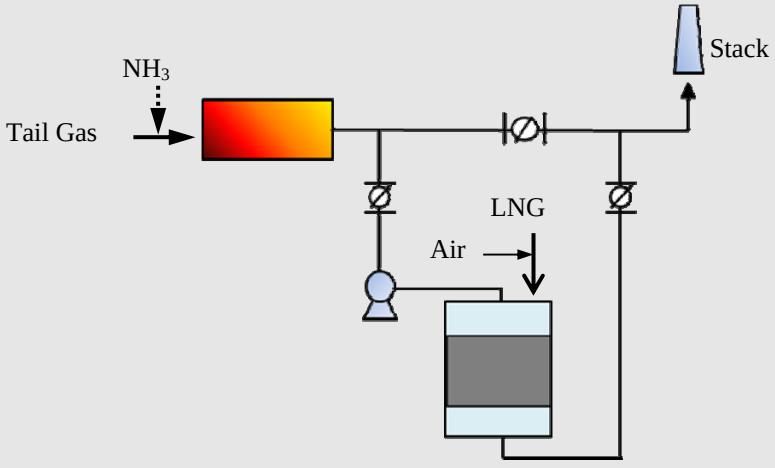

Figure B1-4. Overview of the De-N_2O process in Plant I and II

(c) Information on the implementation and actual operation of the project activity

The information on the implementation and actual operation of the project activity including relevant dates is summarized as following table

Table B1-1. The information on the implementation and actual operation of the project activity

The information on the implementation and actual operation of the project activity	Relevant dates (dd/mm/yyyy)	
	Plant I	Plant II
Starting Construction of N_2O abatement system	16/11/2010	16/11/2010
Commissioning start	20/04/2011	27/04/2011
Starting continued normal operation	02/05/2011	02/05/2011
Regular overhaul (period 2)	08/10/2011 ~20/10/2011	None
Regular overhaul (period 4)	11/10/2012 ~24/10/2012,	11/10/2012 ~29/10/2012,

In order to avoid that the operation of the caprolactam production plant is manipulated in a way to increase the N_2O generation, thereby increasing the CERs, the operating temperature and pressure of the ammonia oxidation reactor (AOR), and NH_3 input to the AOR, have been monitored every working day. During the monitoring period 4, the actual average daily AOR operation conditions are monitored as below Table B1-2

Table B1-2. Summary of the AOR operation data

		$T_{g,a}$ (°C)	$T_{g,b}$ (°C)	P_{g-1} (Pa)	$A_{OR,d-1}$ (tonNH_3/d)
Plant I	Permit range in PDD	656.57~731.66	662.08~743.92	43,320~98,564	42.250 (Upper limit)
	Actual average in period4	711.03	731.56	82,591	37.16
	The number of days outside permit range	12	17	12	none
		$T_{g,c}$ (°C)	$T_{g,d}$ (°C)	P_{g-2} (Pa)	$A_{OR,d-2}$ (tonNH_3/d)
Plant II	Permit range in PDD	738.95~774.85	734.53~770.57	79,317~96,381	44.557 (Upper limit)
	Actual average in period4	750.21	745.95	85,905	41.26
	The number of days outside permit range	18	19	18	none

The all of catalysts for ammonia oxidation reaction used during the crediting period are the same as those described in registered PDD.

Table B1-3. The status of ammonia oxidation catalysts installed in AOR

		Plant I	Plant II
Historical supplier of AOR catalyst $G_{com,hist}$		Pt(90%): Rh(10%)	Pt(90%): Rh(10%)
Historical composition of AOR catalyst $G_{sup,hist}$		Johnson Matthey	Johnson Matthey
in period 4	The composition (G_{com})	Pt(90%): Rh(10%)	Pt(90%): Rh(10%)
	Supplier (G_{sup})	Johnson Matthey	Johnson Matthey

In the case of a nitric acid plant or a caprolactam plant using the Raschig process, baseline emissions are limited to the design capacity of the existing nitric acid or caprolactam production plant. If the actual production of caprolactam ($P_{product}$) exceeds the design capacity ($P_{product,max}$) then emissions related to the production above $P_{product,max}$ will not be claimed for the baseline scenario. Therefore $P_{product}$ of each plant should be monitored.

All of the data for production of caprolactam for this period were listed in detail in the emission reductions calculation spreadsheet.

Table B1-4. The information of Caprolactam production

		Plant I	Plant II
PDD	$P_{product,\ max}$ (tCaprolactam/yr)	63,307	64,965
	Maximum operating day(day/yr)	363	355
	Average daily output(ton/day)	174	183
Period 4	Sub-total output for period(tCaprolactam/day)	28,963	31,879
	No. of operating days(day/period)	206	206
	Average daily output(ton/day)	141	155

The actual production of caprolactam ($P_{product}$) did not exceed the design capacity ($P_{product,max}$) .

(d) Events or situations occurred during the monitoring

(1) Events of Plant I

Events information

Sites	No.	Date (dd/mm/yy) & Time		description
		from	to	
N_2O Abatement System (NAS)	1	09/06/2012, 10:04	09/06/2012, 13:33	Failure in DCU(Data Communication Unit)
	2	12/06/2012, 18:19	12/06/2012, 18:46	Failure in DCU(Data Communication Unit)
	3	26/06/2012, 15:35	26/06/2012, 16:50	Solenoid valves to open outlet damper in NAS were replaced.
	4	07/07/2012, 17:50	07/07/2012, 20:58	Failure in DCU(Data Communication Unit)
	5	09/07/2012, 09:00	14/07/2012, 00:35	The spring and piston in Actuator were replaced. De-N_2O catalyst was compensated for loss.
	6	15/07/2012, 11:32	16/07/2012, 08:15	Solenoid valves to open inlet damper in NAS were replaced.
	7	27/08/2012, 03:10	28/08/2012, 20:13	Failure in DCU(Data Communication Unit)
	8	07/09/2012, 17:19	08/09/2012, 00:15	Failure in DCU(Data Communication Unit)
	9	09/09/2012, 07:04	09/09/2012, 09:45	Failure in DCU(Data Communication Unit)
Product Facility	10	05/07/2012, 04:07	07/07/2012, 02:52	Product facility was loaded down because some part of tube consisting that is leaked.
	11	11/10/2012, 19:22	24/10/2012, 10:30	All facilities of Plant 1 were regularly overhauled.
	12	23/11/2012, 04:30	24/11/2012, 10:48	Air blower was overhauled.
	13	07/12/2012, 05:22	08/12/2012, 10:20	Some equipment to control process broke down.

Action to the events

For the events related N_2O Abatement System (NAS), the data on N_2O concentration (CI_{N2O-1}, CO_{N2O-1}) and volume flow rate (F_{TI-1} , F_{TE-1}) measured at the inlet and exit of the destruction facility in Plant I are cancelled. However, the data of the natural gas input (Q_{NG-1}) and CH_4 concentration (CO_{CH4-1}) measured at destruction facility outlet in Plant I are accepted to adopt a conservative manner.

For the events resulted from the malfunctions, inspections, and blackout of product facility in plant I, it is deleted that not only the data indicating AOR operation conditions ($A_{OR,d-1}$, P_{g-1} , T_{g-a} , T_{g-b}) ,and productivity of the caprolactam ($P_{product-1}$), but also the data on N_2O concentration (CI_{N2O-2}, CO_{N2O-2}) and volume flow rate (F_{TI-1} , F_{TE-1}) which are measured in N_2O Abatement System (NAS) in plant I.

Sites	No.	Relevant Time to Data cancelling		Parameters of the cancelled data
		from	to	
N_2O Abatement System (NAS)	1	09/06/2012, 10:00	09/06/2012, 14:00	• N_2O concentrations (CI_{N2O-1}, CO_{N2O-1}) • volume flow rate (F_{TI-1} , F_{TE-1})
	2	12/06/2012, 18:00	12/06/2012, 19:00	
	3	26/06/2012, 15:00	26/06/2012, 17:00	
	4	07/07/2012, 17:00	07/07/2012, 21:00	
	5	09/07/2012, 09:00	14/07/2012, 01:00	
	6	15/07/2012, 11:00	16/07/2012, 09:00	
	7	27/08/2012, 03:00	28/08/2012, 21:00	
	8	07/09/2012, 17:00	08/09/2012, 01:00	
	9	09/09/2012, 07:00	09/09/2012, 10:00	
Product Facility	10	05/07/2012, 04:00	07/07/2012, 03:00	• N_2O concentrations (CI_{N2O-1}, CO_{N2O-1}) • volume flow rate (F_{TI-1} , F_{TE-1}) • AOR operation conditions ($A_{OR,d-1}$, P_{g-1} , T_{g-a} , T_{g-b}) • Plant output of caprolactam ($P_{product-1}$)
	11	11/10/2012, 19:00	24/10/2012, 11:00	
	12	23/11/2012, 04:00	24/11/2012, 11:00	
	13	07/12/2012, 05:00	08/12/2012, 11:00	

(2) Events of Plant II

Events information

Sites	No.	Date (dd/mm/yy) & Time		description
		from	to	
N_2O Abatement System (NAS)	1	15/07/2012, 11:27	15/07/2012, 14:41	Failure in DCU(Data Communication Unit)
	2	16/07/2012, 17:55	17/07/2012, 08:37	Failure in DCU(Data Communication Unit)
	3	23/08/2012, 20:45	23/08/2012, 21:57	Failure in DCU(Data Communication Unit)
	4	07/09/2012, 17:14	08/09/2012, 00:23	Failure in DCU(Data Communication Unit)
Product Facility	5	27/07/2012, 12:20	27/07/2012, 17:25	Washing tube in gas pre-heater for operating SCR
	6	09/08/2012, 08:25	09/08/2012, 10:50	Washing tube in gas pre-heater for operating SCR
	7	21/08/2012, 13:46	21/08/2012, 18:22	Washing tube in gas pre-heater for operating SCR
	8	11/10/2012, 03:00	29/10/2012, 18:20	All facilities of Plant 2 were regularly overhauled

Action to the events

For the events related N_2O Abatement System (NAS), the data on N_2O concentration (CI_{N2O-2}, CO_{N2O-2}) and volume flow rate (F_{TI-2} , F_{TE-2}) measured at the inlet and exit of the destruction facility in Plant II are cancelled. However, the data of the natural gas input (Q_{NG-2}) and CH_4 concentration (CO_{CH4-2}) measured at destruction facility outlet in Plant II are accepted to adopt a conservative manner.

For the events resulted from the malfunctions, inspections, and blackout of product facility in plant II, it is deleted that not only the data indicating AOR operation conditions ($A_{OR,d-2}$, P_{g-2} , T_{g-c} , T_{g-d}) ,and productivity of the caprolactam ($P_{product-2}$), but also the data on N_2O concentration (CI_{N2O-2}, CO_{N2O-2}) and volume flow rate (F_{TI-2} , F_{TE-2}) which are measured in N_2O Abatement System (NAS) in plant II.

Sites	No.	Relevant Time to Data cancelling		Parameters of the cancelled data
		from	to	
N_2O Abatement System (NAS)	1	15/07/2012, 11:00	15/07/2012, 15:00	• N_2O concentrations (CI_{N2O-1}, CO_{N2O-1}) • volume flow rate (F_{TI-1} , F_{TE-1})
	2	16/07/2012, 17:00	17/07/2012, 09:00	
	3	23/08/2012, 20:00	23/08/2012, 22:00	
	4	07/09/2012, 17:00	08/09/2012, 01:00	
Product Facility	5	27/07/2012, 12:00	27/07/2012, 18:00	• N_2O concentrations (CI_{N2O-1}, CO_{N2O-1}) • volume flow rate (F_{TI-1} , F_{TE-1}) • AOR operation conditions ($A_{OR,d-1}$, P_{g-1} , T_{g-a} , T_{g-b}) • Plant output of caprolactam ($P_{product-1}$)
	6	09/08/2012, 08:00	09/08/2012, 19:00	
	7	21/08/2012, 13:00	21/08/2012, 19:00	
	8	11/10/2012, 03:00	29/10/2012, 19:00	

B.2. Post registration changes

B.2.1. Temporary deviations from registered monitoring plan or applied methodology

>>

None

B.2.2. Corrections

>>

None

B.2.3. Permanent changes from registered monitoring plan or applied methodology

>>

None

B.2.4. Changes to project design of registered project activity

>>

None

B.2.5. Changes to start date of crediting period

>>

None

B.2.6. Types of changes specific to afforestation or reforestation project activity

>>

N/A

SECTION C. Description of monitoring system

>>

(a) Monitoring points to be measured

(1) Monitoring Points in Plant I

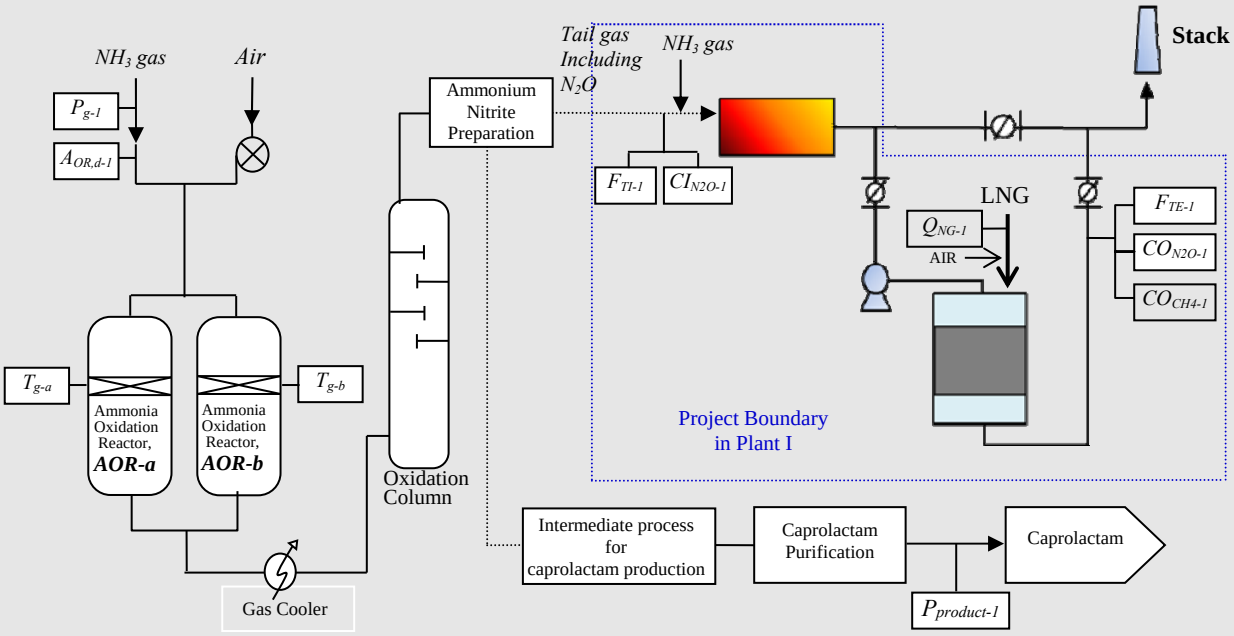

Figure C1. Monitoring Points in Plant I

Parameter	Description	Tag No.
$A_{OR,d-1}$	Actual ammonia flow rate to AOR in Plant I	FIC-1201
P_{g-1}	Actual operating pressure of the AOR-a, b in Plant I	PI-1205
T_{g-a}	Actual operating temperature of the AOR-a in Plant I	TI-1204
T_{g-b}	Actual operating temperature of the AOR-b in Plant I	TI-1206
F_{TI-1}	Volume flow rate at the inlet of the destruction facility in Plant 1	FI-1521
F_{TE-1}	Volume flow rate at the exit of the destruction facility in Plant 1	FI-1522
CI_{N2O-1}	N_2O concentration at destruction facility inlet in Plant I	AI-1521
CO_{N2O-1}	N_2O concentration at destruction facility outlet in Plant I	AI-1522(a)
Q_{NG-1}	Additional natural gas input for re-heating the tail gas in Plant I	FI-1523
CO_{CH4-1}	CH_4 concentration at destruction facility outlet in Plant I	AI-1522(b)
$P_{product-1}$	Plant output of caprolactam in Plant I	FR-7705

Some tag numbers of measuring devices were specified to avoid confusion, because the same tag number had been allocated to two kind of different measuring devices described in PDD. Therefore new tag numbers were given to be clearly identified as follows:

	Parameters	Tag No. in PDD	Actual Tag No. in Period4
Plant I	CO_{N2O-1}	AI-1522	AI-1522(a)
	CO_{CH4-1}	AI-1522	AI-1522(b)

(2) Monitoring Points in Plant II

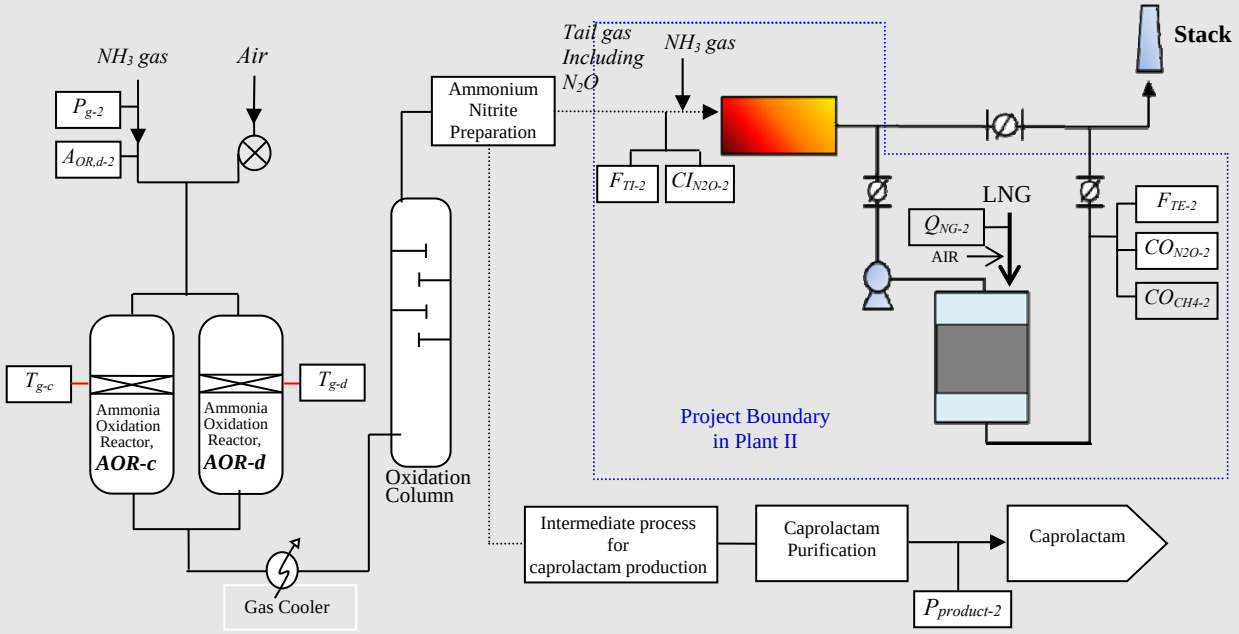

Figure C2. Monitoring Points in Plant II

Parameter	Description	Tag No.
$A_{OR,d-2}$	Actual ammonia flow rate to AOR in Plant II	2FIC-1201
P_{g-2}	Actual operating pressure of the AOR-c, d in Plant II	2PI-1205
T_{g-c}	Actual operating temperature of the AOR-c in Plant II	2TI-1204
T_{g-d}	Actual operating temperature of the AOR-d in Plant II	2TI-1206
F_{TI-2}	Volume flow rate at the inlet of the destruction facility in Plant II	2FI-1521
F_{TE-2}	Volume flow rate at the exit of the destruction facility in Plant II	2FI-1522
CI_{N2O-2}	N_2O concentration at destruction facility inlet in Plant II	2AI-1521
CO_{N2O-2}	N_2O concentration at destruction facility outlet in Plant II	2AI-1522(a)
Q_{NG-2}	Additional natural gas input for re-heating the tail gas in Plant II	2FI-1523
CO_{CH4-2}	CH_4 concentration at destruction facility outlet in Plant II	2AI-1522(b)
$P_{product-2}$	Plant output of caprolactam in Plant II	2FI-7705

Some tag numbers of measuring devices were specified to avoid confusion, because the same tag number had been allocated to two kind of different measuring devices described in PDD. Therefore new tag numbers were given to be clearly identified as follows:

	Parameters	Tag No. in PDD	Actual Tag No. in Period 4
Plant II	CO_{N2O-2}	2AI-1522	2AI-1522(a)
	CO_{CH4-2}	2AI-1522	2AI-1522(b)

(b) Data collection procedure

The data of the AOR operating parameters ($A_{OR,}$ *Tg, Pg*) and the productivity of caprolactam are logged and stored by the existed DCS (Distributed Control System) which has been independently operated for Plant I and II before starting this project. Besides, DAS (Data Acquisition System) is newly installed to log the relevant data to the N_2O decomposition amount and CH_4 emission by operating N_2O abatement system. DAS consists of an 'Electronic Evaluation Unit (EEU)' and two of 'Data Communication Units (DCUs)' located at Plant I and II.

Major function of DCU is to record the raw measurement data from Automated Measuring System (AMS), and to transmit those to EEU. DCU can store temporarily the record of raw measurement data with the ring memory of 16days minute values. In addition, the data of AOR operation and caprolactam productivity are delivered from DCS and recorded by DCU respectably, and then transmitted to EEU. Q_{NG} is measured by Flow meter separately installed from AMS and CO_{CH4} are also measured at the outlet by dual channel-NDIR by which the concentration of N_2O and CH_4 is measured separately. Therefore it is aggregated, recorded and stored by EEU that not only the AMS data but also the AOR data and productivity data. However, if there is a discrepancy between the DCS data and the EEU and/or DCU data, DCS data should be taken.

EEU satisfies the requirements described in AM0028 / Version 05 as below:

(a) Evaluation unit needs to take into account registration, mean average determination, validation, and evaluation;

(b) The system and concept of emission data processing needs to be described;

(c) Protocols and out-prints are required.

With EEU, these raw measurement data transmitted from DCUs are integrated after the measurement uncertainty determined by QAL 2 test is subtracted from them. Then, those are converted to the average values at the end of the every integration interval (1 hour), and validated. Negatively validated average values are set to zero. Validated average values outside the valid calibration range are to be stored with the associated time and with their status and are to be logged on EEU at the end of the day and year. EEU has the storage capacity of 5year-ring memory.

The calibration curve for the measuring instrument is determined using a standard reference method. The validity of the calibration curve is proved by EEU. The validity range for the calibration is specified in the calibration report. This calibration reports are printed and kept for back-up.

External hard disk drive (HDD) is installed for back-up and long storage of the data and relevant reports for verification, replaced by new one every 4 years, old HDDs are kept holding with attention during the 10years of crediting period and 2 additional years according to AM0028 / Version 05.

Table C1. The information of the data collection and storage devices except DCS

		Supplier	Model No.	Serial No.
DCU(Data Communication Unit)	Plant I	DURAG	D-EMS 500 KE	1301581
	Plant II	DURAG	D-EMS 500 KE	1301582
EEU (Electronic Evaluation Unit)		DURAG	D-EMS 2000 SWE	1301567
External Hard disk drive(HDD) for backup		DURAG	D-EMS 2000 RED	1301578

The role of the new PC for back-up is to display and record the hourly data from EEU, the monthly data of supplied LNG, and the other information including the events list, working diary and so on.

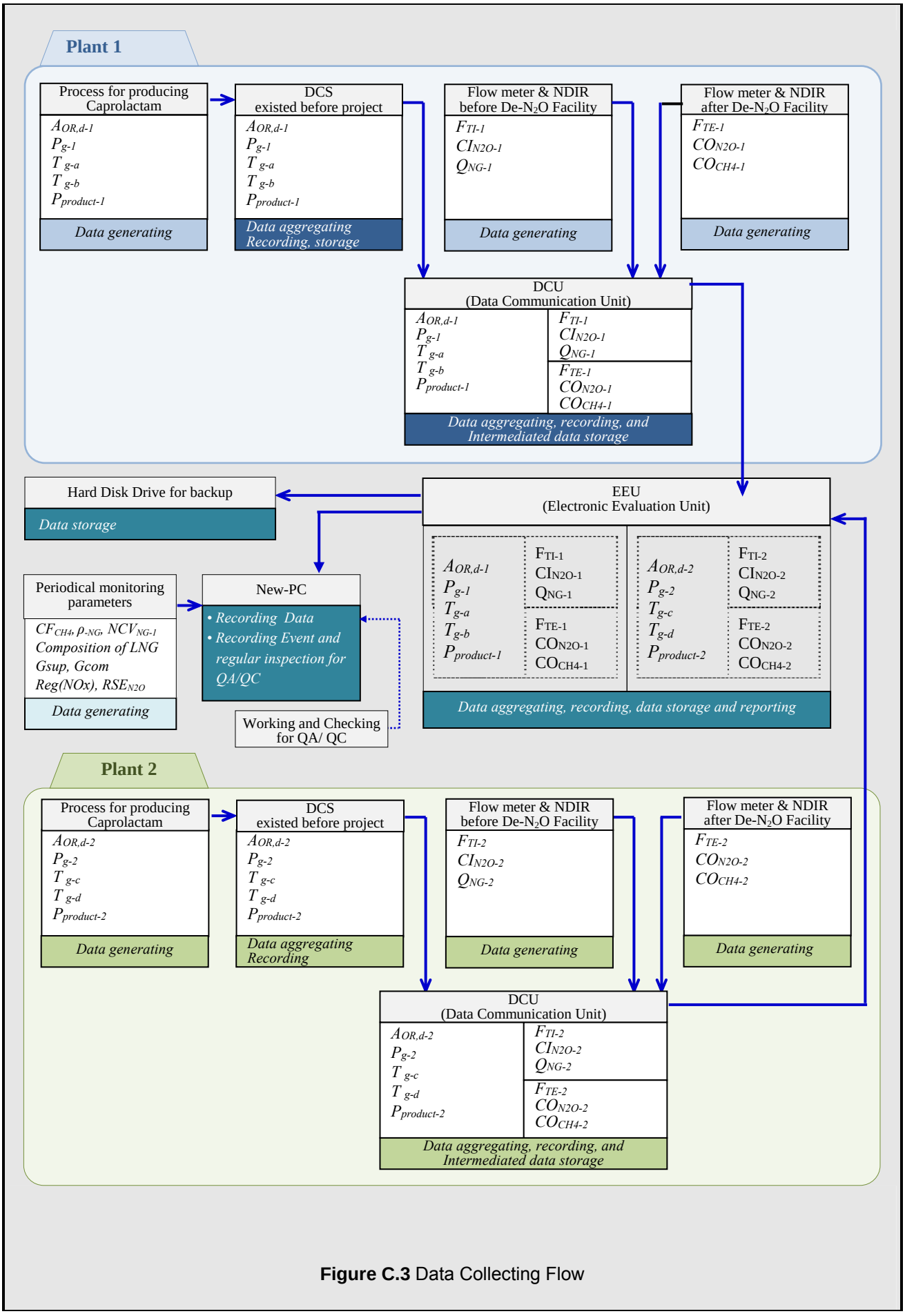

Figure C.3 Data Collecting Flow

(c) Organizational structure, roles and responsibilities of personel

(1) Organization Structure

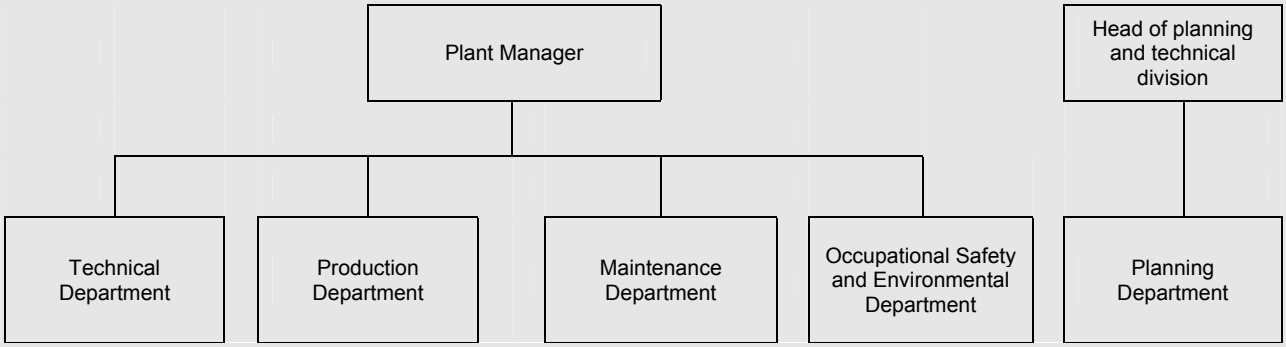

Figure C.4 The scheme of the operational and management structure

(2) Roles and responsibilities of personnel

Plant Manager

The Plant Manager takes overall responsibility for the operation and maintenance of the N_2O monitoring system. In addition, the Plant Manager has authority to approve monitoring report provided by the Technical Department.

Production Department

The responsible Production Engineers in Production Department are in charge of the operation and supervision of N_2O monitoring system that will be implemented to record plant operation data.

Technical Department

Monitoring engineers in Technical Department are responsible for collecting, validating and processing the data to determine GHG emission reduction and making report periodically. Moreover, the monitoring engineer is in charge of archiving the data as well. The monitoring engineers archive all required data and reports for verification.

Maintenance Department

Maintenance Department is responsible for maintaining and repairing the instrument associated with this project. Calibration for instruments is concerned by maintenance department as well.

Occupational Safety and Environment Department

The OSHES Department plays a role for indicating the direction and managing according to the monitoring plan.

Planning Department

Planning Department conducts the internal audit of N_2O monitoring system periodically.

(d) Emergency procedures for the monitoring system

In case of the data deviation, following procedures are taken.

(a) Production Engineer in Production Department identifies whether the deviation results from processing or other factors such as temperature and pressures.

(b) Production engineer compares the deviated data with other parameter data if the deviation results from processing.

(c) If the reason for the data deviation is not identified, production engineer informs Maintenance Department to correct the error after inspecting all gauges and analyzers.

If the data deviation is not covered by procedures above, Technical Department makes the decision to correct figures or to abandon the data. In addition, any data correction is in compliance with the applied methodology and done in a conservative bias

When the malfunction of measuring instruments is occurred, following procedures are taken.

(a) If production engineer recognizes the malfunction of measuring instruments, he informs person in Maintenance Department of this abnormal situation.

(b) Maintenance Department estimates whether performing repairing action to solve problem is appropriate or not.

(c) If it is decided that self-repairing by Maintenance Department is appropriate, self-repairing is carried out. However, if the instrument is out of repair, Maintenance Department requests external institution specialized in repairing to have it serviced.

If measuring devices have to be replaced, related supporting evidences should be checked and kept by Maintenance Department, in order to demonstrate that the quality of the replaced measuring devices is the same as the quality grade of existed devices, before the copies of the supporting evidences to replaced devices should be delivered to and kept in the Technical Department.

Specially, if any malfunction situation of the measuring devices composing AMS(Automated measuring system) is continued during the 8hrs after it is detected, Maintenance Department should request the service of official measuring agency to measuring the N_2O concentration or flow rate at the monitoring points of inlet and outlet of N_2O decomposition system. If the services by the official measuring agency cannot be taken for some unavoidable reason, it will be taken instead of measuring by the external official measuring agency that the AMS data measured at the most similar operating condition among those of the recent 1 month just before the abnormal situation is happen, with the conservative understanding of that the N_2O concentration of inlet is replaced with the lowest number, and that of outlet is with highest one.

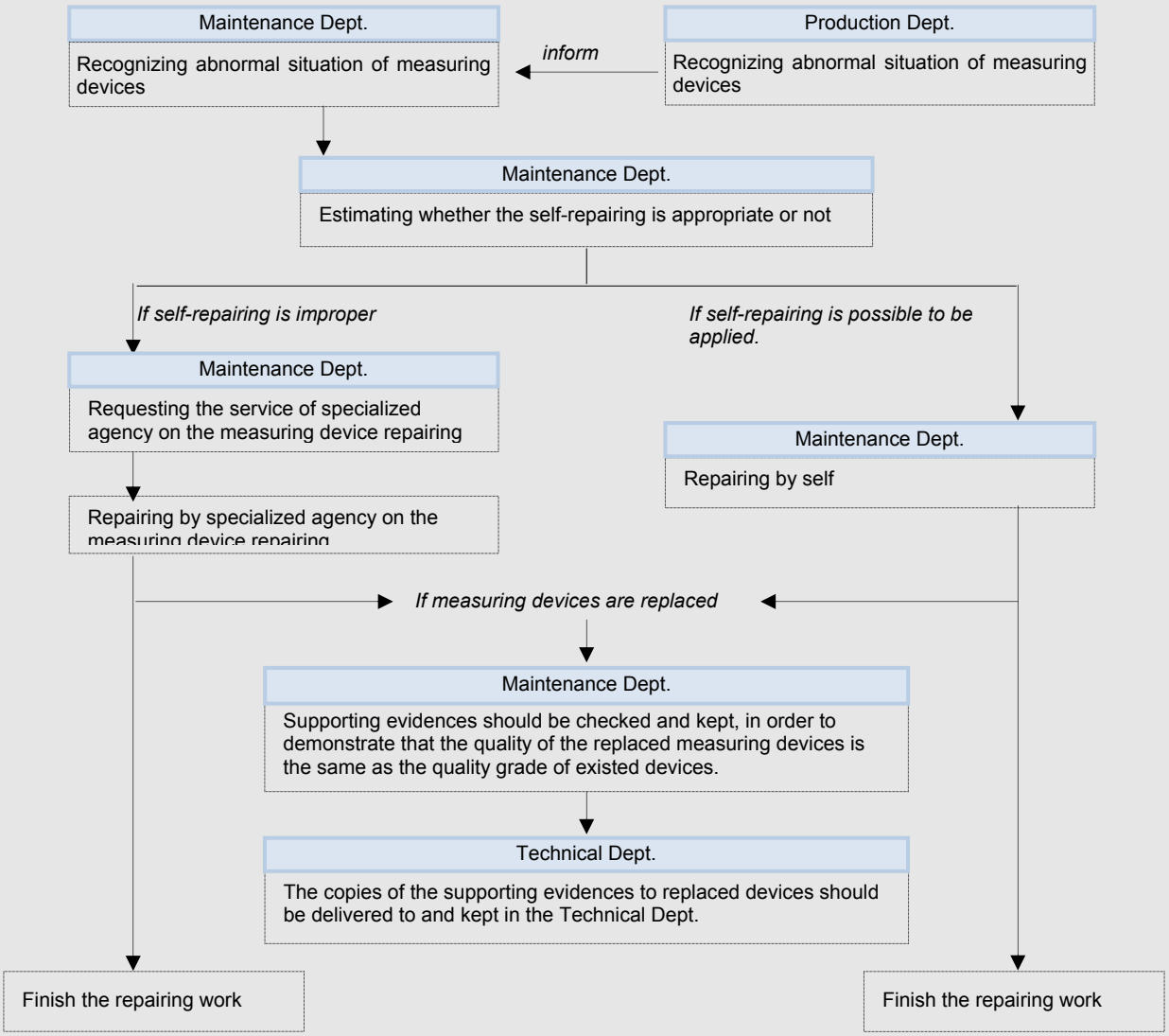

Figure C.5 Emergency Procedures for malfunctions of measuring devices in general

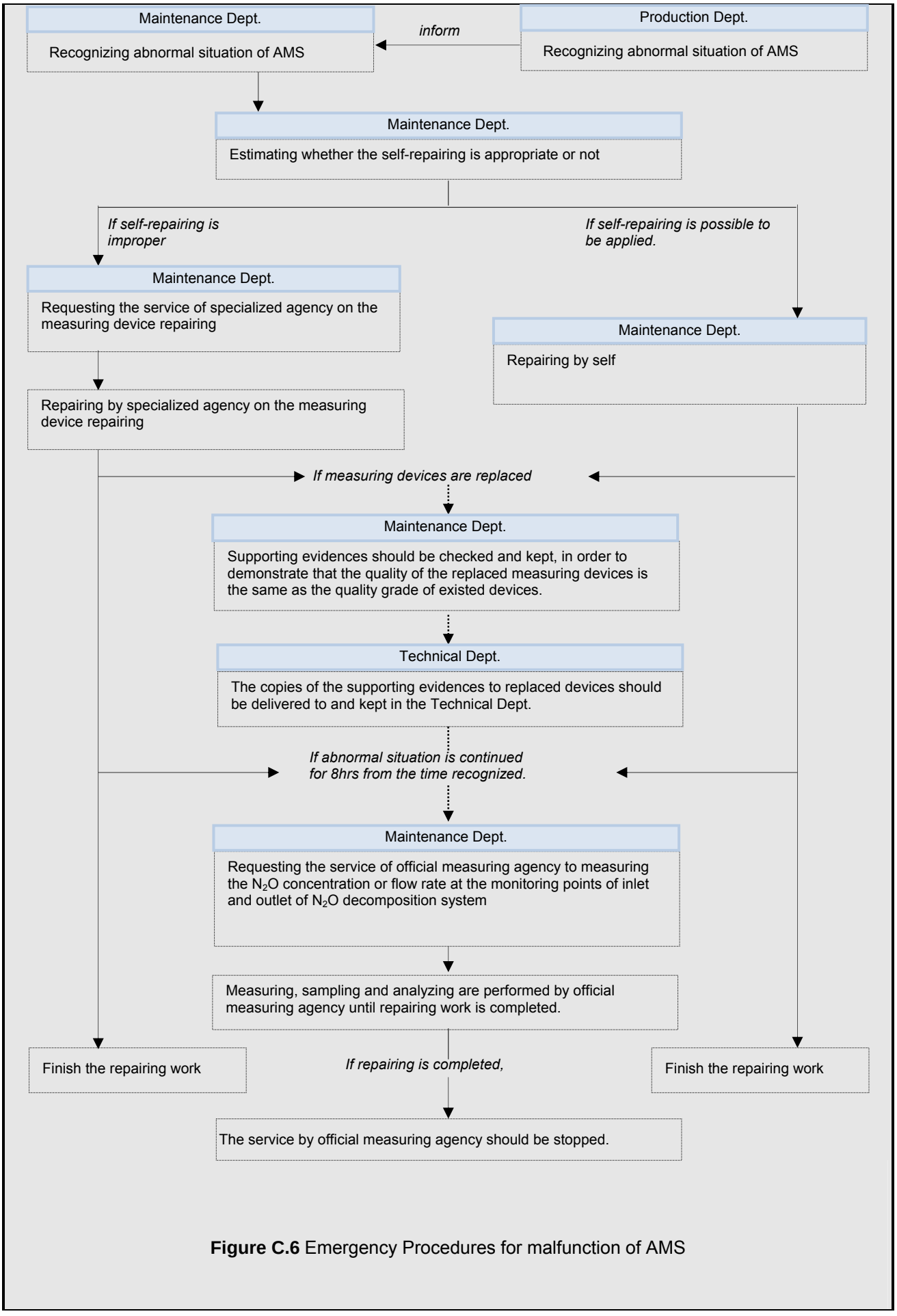

Figure C.6 Emergency Procedures for malfunction of AMS

(e) Reporting

- **Daily report** consists of the parts printed out from EEU and from New-PC. EEU report is to show the data generated by AMS and related to the AOR operation condition and to the productivity of caprolactam. Daily value of each parameter is calculated based on hourly average or hourly total value on the EEU report. The situation of the AMS failure is also documented on the EEU report. The other hand, new-PC daily report is about checking and maintaining the measuring device and N_2O abatement system, and about monitoring events.

- **Monthly report** integrates the data and information in daily reports. LNG information is also reported monthly. Periodical monitoring parameters such as the composition and supplier of AOR catalysts, the national regulation on NOx and N_2O are checked by monthly report too.

- **Annual report** is a bunch of monthly report files.

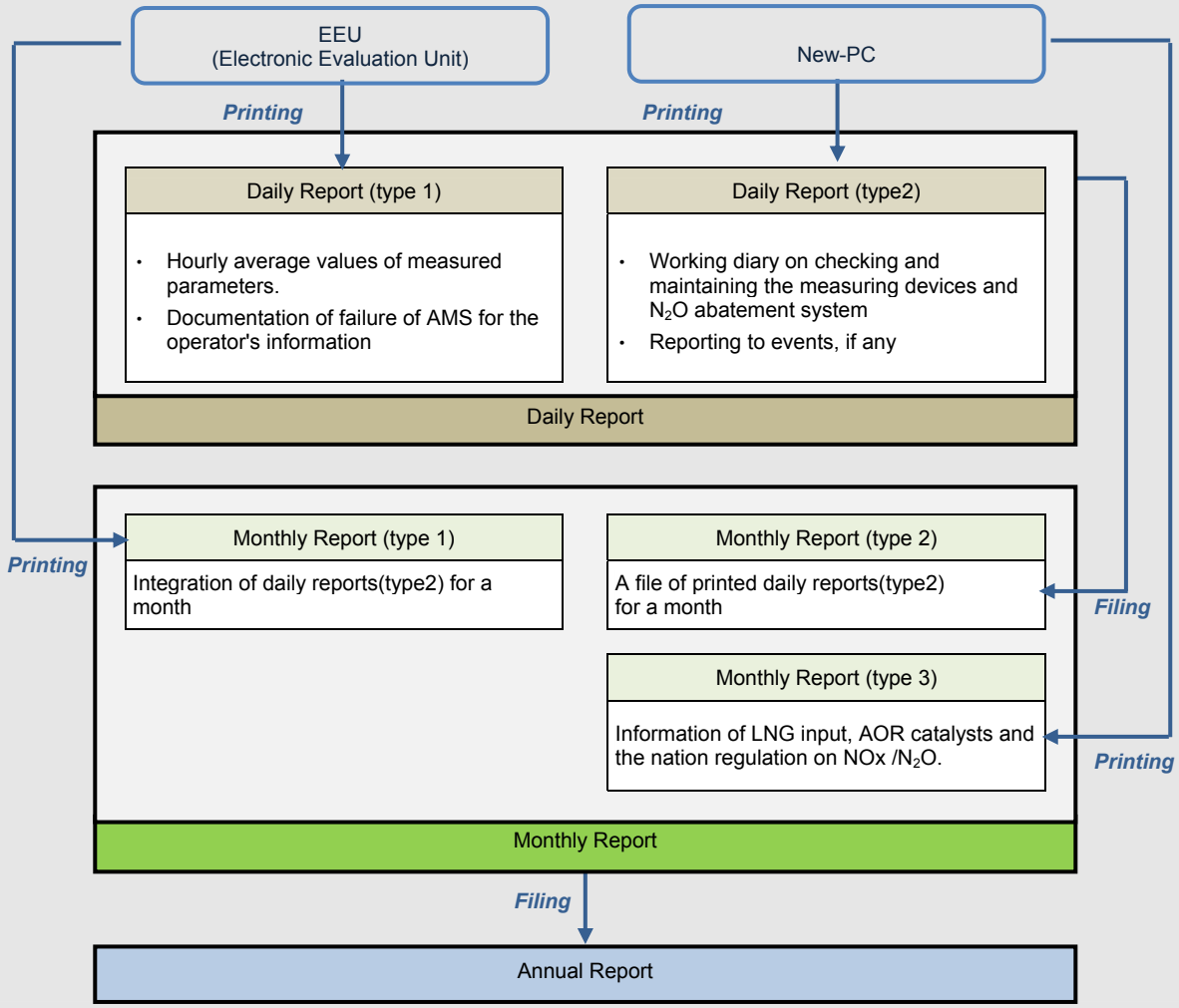

Figure C.7 The consists of the periodical reports

(f) Quality Assurance of AMS(Automated measuring system)

AMS(Automated measuring system) has been applied to measure the amount of N_2O emission at the two monitoring points of the inlet and outlet of N_2O destruction facility of each plant involved in this project. By AMS, the concentration of N_2O and the volume flow rate of tail gas are measured simultaneously(F_{Ti}, CI_{N2O}, and F_{TE}, CO_{N2O}) at same basis (wet or dry), and these values are expressed on the same basis (wet or dry) with correcting to normal conditions (101.324kPa, 0deg C) through the algorithm based on procedures of EN14181.

"European Norm EN14181: Quality assurance of automated measuring systems, 2004" is selected as a guidance document to the Quality Assurance and Control procedure of the AMS for this project. This means that the three levels of quality assurance tests(QAL1, QAL2 and QAL3) and one annual functional test must be carried out regarding the selection, installation, and operation of AMS under the monitoring methodology in AM0028(ver.05).

Quality assurance of tested AMS (:QAL1)

The quality assurance of tested AMS was accomplished with that the flow meters and N_2O gas analyzers having the performance certificate with calculation uncertainty were selected as summarized in following tables.

Table C.2 (a) Information of the quality assurance of tested AMS located in Plant I

Para-meters	Type	model	serial number	Standard for Performance certification	Certificate No.	The date of Certificate Issued (dd/mm/yyyy)	Approved Methods to calculate of uncertainty
F_{TI-1}	Ultrasonic flow meter	D-FL 200 System	HEAD A: 1217007 HEAD B: 1217008 EVALUATION UNIT : 1216861 CASE OF EVALUATION : 1216999	MCERTS	Sira MC 060072/01	22/05/2007	-
CI_{N2O-1}	Non-dispersion infrared absorption analyzer (NDIR)	ULTRAMAT 6	AO-748	TUV	Report Nr. 1290727	May 2009	-
				TUV	BB-EG1-KAR Gr02X	29/07/2003	EN 50016 EN 60079-14 Guidelines for explosion protection of GB Chemie(GRG 104)
				FM Approvals	3016050	15/07/2003	-
				CSA INTERNATIONAL	1431560	17/04/2003	-
F_{TE-1}	Ultrasonic flow meter	D-FL 200 System	HEAD A: 1217009 HEAD B: 1217010 EVALUATION UNIT : 1216862 CASE OF EVALUATION : 1217001	MCERTS	Sira MC 060072/01	22/05/2007	-
CO_{N2O-1}	NDIR	ULTRAMAT 6	AO-750	TUV	Report Nr. 1290727	May 2009	-
				TUV	BB-EG1-KAR Gr02X	29/09/2003	EN 50016 EN 60079-14 Guidelines for expolosion protection of GB Chemie(GRG 104)
				FM Approvals	3016050	15/07/2003	-
				CSA INTERNATIONAL	1431560	17/04/2003	-

Table C.2 (b) Information of the quality assurance of tested AMS located in Plant II

Para-meters	Type	model	serial number	Standard for Performance certification	Certificate No.	The date of Certificate Issued (dd/mm/yyyy)	Approved Methods to calculate of uncertainty
F_{TI-2}	Ultrasonic Flow meter	D-FL 200 System	HEAD A: 1217011 HEAD B: 1217012 EVALUATION UNIT : 1216866 CASE OF EVALUATION : 1217002	MCERTS	Sira MC 060072/01	22/05/2007	-
CI_{N2O-2}	NDIR	ULTRAMAT 6	AO-749	TUV	Report Nr. 1290727	May 2009	-
				TUV	BB-EG1-KAR Gr02X	29/09/2003	EN 50016 EN 60079-14 Guidelines for expolosion protection of GB Chemie(GRG 104)
				FM Approvals	3016050	15/07/2003	-
				CSA INTERNATIONAL	1431560	17/04/2003	-
F_{TE-2}	Ultrasonic Flow meter	D-FL 200 System	HEAD A: 1217013 HEAD B: 1217014 EVALUATION UNIT : 1216867 CASE OF EVALUATION : 1217003	MCERTS	Sira MC 060072/01	22/05/2007	-
CO_{N2O-2}	NDIR	ULTRAMAT 6	AO-751	TUV	Report Nr. 1290727	May 2009	-
				TUV	BB-EG1-KAR Gr02X	29/09/2003	EN 50016 EN 60079-14 Guidelines for expolosion protection of GB Chemie(GRG 104)
				FM Approvals	3016050	15/07/2003	-
				CSA INTERNATIONAL	1431560	17/04/2003	-

Quality assurance of installation and calibration of AMS (:QAL2)

QAL 2 has been performed two times according to the Standard Reference Measurement Method (23/05/2011~27/05/2011 and 26/09/2011~29/09/2011) by AIR-TEC, which is the one of the organizations having an accredited quality assurance system on ISO/IEC 17025.

The results to the tests for QAL2 were summarized on the QAL 2 reports in the major items following:

(a) Section of the location of measurement

(b) Duly installation of the monitoring equipment

(c) Correct choice of measurement range

(d) Calibration of AMS using the standard-Reference-Method(SRM) as guidance

(e) Calibration curve either as linear regression or as straight line from absolute zero to centre of a scatter-plot

(f) Calibration of the standard deviation at the 95% confidence interval

Continuous quality Assurance through the local operator/manager (:QAL3)

QAL 3 has been implemented since the project start up. This includes:

- Permanent quality assurance during the plant operation by the operating staff
- Assurance of reliable and correct operation of the monitoring equipment
- Regular controls : zero point, span, drift, meet schedule of manufacturer maintenance intervals

Annual Surveillance test (AST)

Annual Surveillance test has been carried out in May of 2012 (14/05/2012~17/05/2012).

(g) Conservative calculation on tail gas flow

Measurement value by a flow meter at inlet of destruction facility (F_{TI}) and Measurement value by a flow meter at outlet of destruction facility (F_{TE}), both parameters shall be cross checked to ensure that no leak of N_2O is taking place, and in case of discrepancy, conservative calculation of emission reduction is provided. In order to achieve conservative approach, the measured inlet flow (F_{TI}) would be adjusted to the value (F_{TI}*) by the below equation.

$$F_{TI}^{*} = \min\left[F_{TI} ; \left(\frac{F_{TE}}{1+VEF} - Q_{NG} \times \frac{Q_{NG\ combustion\ gas}}{Q_{NG}} \right) \right]$$

Where:

F_{TI}^{*}	: Conservative volume flow at the inlet of destruction facility used for emission reduction calculation (Nm^3/h)
F_{TI}	: Measurement value by a flow meter at inlet of destruction facility (Nm^3/h)
FTE	: Measurement value by a flow meter at outlet of destruction facility (Nm^3/h)
Q_{NG}	: Natural gas input for re-heating the tail gas (Nm^3/h)
$Q_{NG\ combustion\ gas}$	: Combustion gas of natural gas (Nm^3/h)
VEF	: Volumetric Expansion Factor

For monitoring, the gas generated by combusting natural gas($Q_{NG\ combustion\ gas}$) has been estimated on the supposition that air input according to the theoretical oxygen demand on the natural gas composition which information is provided by the natural gas supplier for Capro (Kyung Dong city gas CO., Ltd).

And for the conservative approach, any volume change from De-NOx and/or De-N_2O system will be considered by the Volumetric Expansion Factor (VEF). Before the first monitoring period, the Volumetric Expansion Factor (VEF) was determined as 0.001 which was provided by CRI, N_2O abatement catalysts supplier. This value of VEF is applied as a fixed official value.

(h) Training

The supplier of the NDIR system provided complete training to the monitoring engineers in charge of operation and maintenance of the monitoring system. The provider of the De-N2O system, (Hyosung Ebara Engineering Co., Ltd.) initiated the operation technique for the system to the staff in the Technical department of Capro.

SECTION D. Data and parameters

D.1. Data and parameters fixed ex ante or at renewal of crediting period

Data/Parameter	GWP_{N2O}
Unit	Not applicable
Description	Global warming potential of the nitrous oxide
Source of data	IPCC, The Second Assessment Report
Value(s) applied	310
Purpose of data	Baseline Emission / Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	GWP_{CH4}
Unit	Not applicable
Description	Global warming potential of the methane
Source of data	IPCC, The Second Assessment Report
Value(s) applied	21
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	$P_{product,\ max}$
Unit	t Caprolactam /yr
Description	Design capacity of caprolactam production of the targeted line
Source of data	PDD
Value(s) applied	$P_{product1,\ max}$: 63,307 ton/yr (design capacity in Plant I) for 363 days $P_{product2,\ max}$: 64,965 ton/yr (design capacity in Plant II) for 355 days Each plant has an individual design capacity.
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$A_{OR,hist}$
Unit	tNH3/day
Description	Maximum of historical ammonia flow rate of the ammonia oxidation reactor (AOR)
Source of data	PDD
Value(s) applied	$A_{OR,hist-1}$: 42.250tNH_3/d (total flow rate for AOR-a and AOR-b in Plant I) $A_{OR,hist-2}$: 44.557tNH_3/d (total flow rate for AOR-c and AOR-d in Plant II)
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$T_{g,hist}$
Unit	^oC
Description	Historical operating temperature range of the ammonia oxidation reactor
Source of data	PDD

Value(s) applied	$T_{g,hist-a}$: 656.57− 731.66°C (for AOR-a in Plant I) $T_{g,hist-b}$: 662.08−743.92 °C (for AOR-b in Plant I) $T_{g,hist-c}$: 738.95− 774.85°C (for AOR-c in Plant II) $T_{g,hist-d}$: 734.53− 770.57°C (for AOR-d in Plant II)
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$P_{g,hist}$
Unit	*Pa gauge*
Description	Historical operating pressure range of the ammonia oxidation reactor
Source of data	PDD
Value(s) applied	$P_{g,hist\_1}$: 43,320− 98,564 Pa gauge (for AOR-a and AOR-b in Plant I) $P_{g,hist\_2}$: 79,317− 96,381 Pa gauge (for AOR-c and AOR-d in Plant II)
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$G_{sup,hist}$
Unit	Not applicable
Description	Historical supplier of the ammonia oxidation catalyst
Source of data	PDD
Value(s) applied	Name of the supplier: Johnson Matthey
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$G_{com,hist}$
Unit	%
Description	Historical composition of the ammonia oxidation catalyst
Source of data	PDD
Value(s) applied	Pt (90%): Rh (10%)
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$OXID_{HC}$
Unit	%
Description	Oxidation factor of natural gas, with two or more molecules of carbon
Source of data	PDD
Value(s) applied	100%
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	EF_{CH4}
Unit	tCO2/tCH4

Description	Emission factor of methane
Source of data	PDD
Value(s) applied	2.75(tCO2/tCH4)
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	ρ_{CH4}
Unit	t/m^3
Description	Density of methane
Source of data	Tool to determine project emissions from flaring gases containing methane
Value(s) applied	0.000716 t/m^3 (0ºC, 1atm)
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	M_i
Unit	hour
Description	Length of measuring interval
Source of data	AMS
Value(s) applied	1 hour (to be measured continuously for 24 hours)
Purpose of data	Baseline Emission Calculation / Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	Reg_{NOx}
Unit	tNO_X/Nm^3
Description	National regulation on NO_X emissions
Source of data	The “Clean Air Conservation Act”, one of the National environmental legislation, Ministry of Environment
Value(s) applied	4.10714×10^{-7} $tNOx/Nm^3$ (as a NO_2 concentration)
Purpose of data	Not applicable
Additional comment	Not applicable

D.2. Data and parameters monitored

Data / Parameter:	$F_{TI,i}$
Unit:	Nm^3/hr
Description:	Volume flow rate at the inlet of the destruction facility
Measured/ Calculated / Default:	Measured
Source of data:	Flow meter with normalizing functions
Value(s) of monitored parameter:	For this period, the average values of F_{TI}

	Plant I ($F_{TI,1}$)	Plant II($F_{TI,2}$)
F_{TI} (Nm^3/hr) average	39,343	39,439

Monitoring equipment:

	Plant I ($F_{TI,1}$)	Plant II($F_{TI,2}$)
Type	Ultrasonic flow meter	Ultrasonic flow meter
Accuracy class	< 2%	< 2%
Serial No.	• HEAD A: 1217007 • HEAD B: 1217008 • Evaluation Unit :1216861 • Case of Evaluation : 1216999	• HEAD A: 1217011 • HEAD B: 1217012 • Evaluation Unit :1216866 • Case of Evaluation : 1217002
Calibration frequency	Every day by Auto calibration manner	Every day by Auto calibration manner
Date of last calibration	31/12/2012	31/12/2012
Validity	Yes	Yes

Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	QAL 1, 2,3 and AST for AMS
Purpose of data:	Baseline Emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$F_{TE,i}$
Unit:	Nm^3/hr
Description:	Volume flow rate at the exit of the destruction facility
Measured/ Calculated / Default:	Measured
Source of data:	Flow meter with normalizing functions
Value(s) of monitored parameter:	For this period, the average values of F_{TE}

	Plant I ($F_{TE,1}$)	Plant II ($F_{TE,2}$)
F_{TE} as Nm^3/hr in average	42,051	46,696

Monitoring equipment:	

	Plant I ($F_{TE,1}$)	Plant II ($F_{TE,2}$)
Type	Ultrasonic flow meter	Ultrasonic flow meter
Accuracy class	< 2%	< 2%
Serial No.	•HEAD A: 1217009 •HEAD B: 1217010 • Evaluation Unit : 1216862 • Case of Evaluation : 1217001	•HEAD A: 1217013 •HEAD B: 1217014 • Evaluation Unit : 1216867 • Case of Evaluation : 1217003
Calibration frequency	Every day by Auto calibration manner	Every day by Auto calibration manner
Date of last calibration	31/12/2012	31/12/2012
Validity	Yes	Yes

Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	QAL 1, 2,3 and AST for AMS
Purpose of data:	Project Emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$CI_{N2O,i}$
Unit:	tN_2O/Nm^3
Description:	N_2O concentration at destruction facility inlet
Measured/ Calculated / Default:	Measured
Source of data:	Non-dispersion infrared absorption analyzer (NDIR)
Value(s) of monitored parameter:	For this period, the average values of CI_{N2O}

	Plant I(CI_{N2O-1})	Plant II(CI_{N2O-2})
$CI_{N2O,i}$ as tN_2O/Nm^3	3.920×10^{-6}	3.193×10^{-6}

Monitoring equipment:	

	Plant I(CI_{N2O-1})	Plant II(CI_{N2O-2})
Type	NDIR	NDIR
Accuracy class (repeatability)	>95%	>95%
Serial No.	AO-748	AO-749
Calibration frequency	Every 2weeks	Every 2weeks
Date of last calibration	26/12/2012	26/12/2012
Validity	Yes	Yes

Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	QAL 1, 2,3 and AST for AMS
Purpose of data:	Baseline Emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$CO_{N2O,i}$
Unit:	tN_2O/Nm^3
Description:	N_2O concentration at destruction facility outlet
Measured/ Calculated / Default:	Measured
Source of data:	Non-dispersion infrared absorption analyzer (NDIR)
Value(s) of monitored parameter:	For this period, the average values of CO_{N2O}

	Plant I(CO_{N2O-1})	Plant II(CO_{N2O-2})
$CO_{N2O,i}$ as tN_2O/Nm^3	4.578×10^{-7}	3.227×10^{-7}

Monitoring equipment:

	Plant I(CO_{N2O-1})	Plant II(CO_{N2O-2})
Type	NDIR	NDIR
Accuracy class (repeatability)	>95%	>95%
Serial No.	AO-750	AO-751
Calibration frequency	Every 2weeks	Every 2weeks
Date of last calibration	26/12/2012	26/12/2012
Validity	Yes	Yes

Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	QAL 1, 2,3 and AST for AMS
Purpose of data:	Project Emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$P_{product,y}$
Unit:	t Caprolactam/yr
Description:	Plant output of caprolactam
Measured/ Calculated / Default:	Measured
Source of data:	The value measured by Mass flow meter
Value(s) of monitored parameter:	

	Plant I ($P_{product-1}$)	Plant II($P_{product-2}$)
$P_{product,\ period,}$ (ton/period)	28,963	31,879

Monitoring equipment:

	Plant I ($P_{product-1}$)	Plant II($P_{product-2}$)
Type	Mass flow meter	Mass flow meter
Accuracy class	Within ± 0.1%	± 0.15%
Serial No.	F1013202000	28 529138
Calibration frequency	Every 2years	Every 2years
Date of last calibration	20/01/2012	16/10/2012[1]
Validity	Yes	Yes

[1] The previous calibration date of this equipment was 07/10/2010 with a scheduled date 07/10/2012, and the last calibration date of this equipment was 16/10/2012. The last calibration was delayed. The results of the error of the delayed calibration is smaller than the maximum permissible error, and the maximum permissible error of this equipment is applied to the measured values taken during the period between 07/10/2012 and 15/10/2012 as per the para 238(a) VVS. See the section E.1 and the emission reduction calculation spreadsheet.

Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Cross-check of amount of the produced caprolactam is performed on the basis of stock change data and weighbridge data.
Purpose of data:	Baseline emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$T_{g,d}$			
Unit:	°C			
Description:	Actual daily (*d*) operating temperature of the ammonia oxidation reactor			
Measured/ Calculated / Default:	Measured			
Source of data:	Thermocouple			
Value(s) of monitored parameter:	Average daily temperature (°C) of AOR in this period			
	Plant I		**Plant II**	
	$T_{g,a}$ (°C)	$T_{g,b}$ (°C)	$T_{g,c}$ (°C)	$T_{g,d}$ (°C)
	711.03	731.56	750.21	745.95

Monitoring equipment:

The measuring instruments for $T_{g,d}$ indicated in the registered PDD were replaced**.** The relevant dates are summarized on following table. Even though the model number and Maker of the new measuring equipment are different from past one described in PDD, the type and the accuracy class of the equipment comply with the requirements in the registered PDD.

	Date on instruments replaced			
	T_{g-a}	T_{g-b}	T_{g-c}	T_{g-d}
Period 1	None	None	None	None
Period 2	None	17/10/2011	None	None
Period 3	None	None	None	None
Period 4	19/10/2012	19/10/2012	21/10/2012	21/10/2012

The information of the measuring instrument for $T_{g,d}$ is as follows:

T_{g-a}	Before 2012 Replacement		After 2012 Replacement	
Type	Thermocouple K		Thermocouple K	
Accuracy class (Maximum error)	300°C	+0.00°C	300°C	-0.7°C
	500°C	+0.35°C	500°C	-0.1°C
	700°C	+0.98°C	700°C	-0.7°C
Serial No.	2170447		124011	
Calibration frequency	Every 2 years		Every 2 years	
Date of last calibration	13/05/2011		18/04/2012	
Validity	Yes		Yes	

T_{g-b}	After 2011 Replacement		After 2012 Replacement	
Type	Thermocouple K		Thermocouple K	
Accuracy class (Maximum error)	300°C	+0.00°C	300°C	-0.7°C
	500°C	+0.35°C	500°C	-0.1°C
	700°C	+0.98°C	700°C	-0.7°C
Serial No.	2170445		124012	
Calibration frequency	Every 2 years		Every 2 years	
Date of last calibration	17/10/2011		18/04/2012	
Validity	Yes		Yes	

Monitoring equipment:

T_{g-c}	Before 2012 Replacement		After 2012 Replacement	
Type	Thermocouple K		Thermocouple K	
Accuracy class (Maximum error)	300°C	-0.7°C	300°C	-0.7°C
	500°C	-0.1°C	500°C	-0.1°C
	700°C	-0.7°C	700°C	-0.7°C
Serial No.	24001		124008	
Calibration frequency	Every 2 years		Every 2 years	
Date of last calibration	23/05/2011		18/04/2012	
Validity	Yes		Yes	

T_{g-d}	Before 2012 Replacement		After 2012 Replacement	
Type	Thermocouple K		Thermocouple K	
Accuracy class (Maximum error)	300°C	-0.7°C	300°C	-0.7°C
	500°C	-0.1°C	500°C	-0.1°C
	700°C	-0.7°C	700°C	-0.7°C
Serial No.	24002		124007	
Calibration frequency	Every 2 years		Every 2 years	
Date of last calibration	23/05/2011		18/04/2012	
Validity	Yes		Yes	

Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.
Purpose of data:	Baseline emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$P_{g,d}$
Unit:	Pa gauge
Description:	Actual operating pressure of the ammonia oxidation reactor on day *d*
Measured/ Calculated / Default:	Measured
Source of data:	Pressure gauge
Value(s) of monitored parameter:	Average daily Pressure (Pa/day) of AOR in this period

	Plant I (P_{g-1})	Plant II (P_{g-2})
$P_{g,d}$ (Pa/day)	82591	85905

Monitoring equipment:	The measuring instruments for P_{g-1} and P_{g-2} indicated in the registered PDD were replaced on 21th October 2012 and 12th October 2012 respectively. The information of the measuring instrument for $P_{g,d}$ is as follows:

Plant I (P_{g-1})	Before replacement	After replacement
Type	Gauge Pressure	Gauge Pressure
Accuracy class	Within ± 0.1%	Within ± 0.1%
Serial No.	10530360183	1211 80055040030
Calibration frequency	Every 2 years	Every 2 years
Date of last calibration	06/01/2012	18/04/2012
Validity	Yes	Yes

Plant II (P_{g-2})	Before replacement	After replacement
Type	Gauge Pressure	Gauge Pressure
Accuracy class	± 0.1%	Within ± 0.1%
Serial No.	10530360212	1211 80055040031
Calibration frequency	Every 2 years	Every 2 years
Date of last calibration	09/03/2012	18/04/2012
Validity	Yes	Yes

Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.
Purpose of data:	Baseline emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$A_{OR,d}$
Unit:	tNH3/day
Description:	Actual ammonia flow rate to the ammonia oxidation reactor (AOR)
Measured/ Calculated / Default:	Measured
Source of data:	Differential pressure transmitter with normalizing functions
Value(s) of monitored parameter:	Average ammonia flow rate a day (tNH_3/day) of AOR in this period

	Plant I ($A_{OR,d-1}$)	Plant II ($A_{OR,d-2}$)
$A_{OR,d}$ (tNH3/day)	37.16	41.26

<table>
<tr><td>Monitoring equipment:</td><td>The measuring instruments for $A_{OR,d}$ indicated in the registered PDD were replaced on 12th October 2012.

The information of the measuring instrument for $A_{OR,d}$ is as follows:
<table>
<tr><th>Plant I ($A_{OR,d-1}$)</th><th>Before replacement</th><th>After replacement</th></tr>
<tr><td>Type</td><td>Differential Pressure</td><td>Differential Pressure</td></tr>
<tr><td>Accuracy class</td><td>Within ± 0.1%</td><td>Within ± 0.1%</td></tr>
<tr><td>Serial No.</td><td>10530360038</td><td>1210 80055040028</td></tr>
<tr><td>Calibration frequency</td><td>Every 2 years</td><td>Every 2 years</td></tr>
<tr><td>Date of last calibration</td><td>06/01/2012</td><td>18/04/2012</td></tr>
<tr><td>Validity</td><td>Yes</td><td>Yes</td></tr>
</table>
<table>
<tr><th>Plant II ($A_{OR,d-2}$)</th><th>Before replacement</th><th>After replacement</th></tr>
<tr><td>Type</td><td>Differential Pressure</td><td>Differential Pressure</td></tr>
<tr><td>Accuracy class</td><td>Within ± 0.1%</td><td>Within ± 0.1%</td></tr>
<tr><td>Serial No.</td><td>10530360080</td><td>1210 80055040029</td></tr>
<tr><td>Calibration frequency</td><td>Every 2 years</td><td>Every 2 years</td></tr>
<tr><td>Date of last calibration</td><td>09/03/2012</td><td>18/04/2012</td></tr>
<tr><td>Validity</td><td>Yes</td><td>Yes</td></tr>
</table>
</td></tr>
<tr><td>Measuring/ Reading/ Recording frequency:</td><td>•Measuring period : Continuously
•Recording frequency : Hourly</td></tr>
<tr><td>Calculation method (if applicable):</td><td>Since this parameter is measured</td></tr>
<tr><td>QA/QC procedures:</td><td>Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.</td></tr>
<tr><td>Purpose of data:</td><td>Baseline emission Calculation</td></tr>
<tr><td>Additional comment:</td><td>Not applicable</td></tr>
</table>

Data / Parameter:	G_{sup}
Unit:	Not applicable
Description:	Supplier of the ammonia oxidation catalyst
Measured/ Calculated / Default:	Not applicable
Source of data:	Supplier information on catalyst delivery confirmation document
Value(s) of monitored parameter:	Johnson Matthey
Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Recording frequency : Date of changing catalyst
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Not applicable

Purpose of data:	Baseline emission Calculation
Additional comment:	Not applicable

Data / Parameter:	G_{com}
Unit:	%
Description:	Composition of the ammonia oxidation catalyst
Measured/ Calculated / Default:	Not applicable
Source of data:	Supplier information on catalyst delivery confirmation document
Value(s) of monitored parameter:	Pt (90)% : Rh(10)%
Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Recording frequency : Date of changing catalyst
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Not applicable
Purpose of data:	Baseline emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$Type_{HC}$
Unit:	Not applicable
Description:	Type of hydrocarbon / Natural gas
Measured/ Calculated / Default:	Not applicable
Source of data:	Natural gassupplier : KyungDong city gas CO., Ltd. This company is one of the city gas companies in the Republic of Korea. The most of natural gas supplied by KyungDong city gas CO., Ltd. is provided from Korea Gas Corporation (hereafter, KOGAS), which imports natural gas from around the world and supplies it to power generation plants, gas-utility companies and city gas companies throughout the country.
Value(s) of monitored parameter:	Natural Gas
Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Monthly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	CF_{CH4}
Unit:	-
Description:	Methane content of hydrocarbon, natural gas
Measured/ Calculated / Default:	Not applicable

Source of data:	Information provided by the natural gas supplier
Value(s) of monitored parameter:	The same kinds of natural gas are supplied to the Plant I and Plant II.

Date	2012							Period
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	4
CF_{CH4}	0.9146	0.9187	0.9177	0.9191	0.9239	0.9241	0.9241	0.9203

Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Recording frequency : Monthly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$Q_{NG,y}$
Unit:	Nm^3
Description:	Natural gas input for re-heating the tail gas
Measured/ Calculated / Default:	Measured
Source of data:	Flow meter with normalizing functions
Value(s) of monitored parameter:	Average daily value of Q_{NG} (Nm^3/day) in this period

	Plant I ($Q_{NG,1}$)	Plant II($Q_{NG,2}$)
Q_{NG} (Nm^3/day)	554.65	811.28

Monitoring equipment:

	Plant I ($Q_{NG,1}$)	Plant II($Q_{NG,2}$)
Type	Orifice	Orifice
Accuracy class	±0.90%	±0.90%
Serial No.	02319622	02319623
Calibration frequency	Every 2 years	Every 2 years
Date of last calibration	08/03/2012	08/03/2012
Validity	Yes	Yes

Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$Q_{CH4,y,}$
Unit:	Nm^3/yr
Description:	Methane part of the natural gas used.
Measured/ Calculated / Default:	Calculated

Source of data:	Information provided by the natural gas supplier
Value(s) of monitored parameter:	Average values of daily used ($Q_{CH4,d}$) in this period

	Plant I	Plant II
$Q_{CH4,d}$ (Nm^3/day)	454.07	674.46

Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Not applicable
Calculation method (if applicable):	$Q_{CH4,y} = Q_{NG,y} \times CF_{CH4}$
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$Q_{HC,y}$
Unit:	Nm^3 / yr
Description:	The hydrocarbon with two or more molecules of carbon in natural gas
Measured/ Calculated / Default:	Calculated
Source of data:	Information provided by the natural gas supplier
Value(s) of monitored parameter:	Average values of daily used ($Q_{HC,d}$) for this period

	Plant I	Plant II
$Q_{HC,d}$ (Nm^3/day)	39.22	58.55

Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Not applicable
Calculation method (if applicable):	$Q_{HC,y} = Q_{NG,y} \times (1-CF_{CH4})$
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	ρ_{NG}
Unit:	t/Nm^3
Description:	Density of the natural gas
Measured/ Calculated / Default:	Not applicable
Source of data:	Monthly report provided by the fuel supplier
Value(s) of monitored parameter:	The same kinds of natural gas are supplied to the Plant I and Plant II.

Date	2012							Period
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	4
ρ_{NG}	0.8000 $\times 10^{-3}$	0.7916 $\times 10^{-3}$	0.7920 $\times 10^{-3}$	0.7919 $\times 10^{-3}$	0.7874 $\times 10^{-3}$	0.7881 $\times 10^{-3}$	0.7871 $\times 10^{-3}$	0.7912 $\times 10^{-3}$

Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Recording frequency : Monthly

Calculation method (if applicable):	Not applicable
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	ρ_{HC}
Unit:	t/m^3
Description:	Density of the hydrocarbon with two or more molecules of carbon in natural gas
Measured/ Calculated / Default:	Calculated
Source of data:	Information provided by the natural gas supplier
Value(s) of monitored parameter:	The same kinds of natural gas are supplied to the Plant I and Plant II.

Date	2012							Period
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	4
ρ_{HC}	1.6996 $\times10^{-3}$	1.6459 $\times10^{-3}$	1.6395 $\times10^{-3}$	1.6542 $\times10^{-3}$	1.6542 $\times10^{-3}$	1.6659 $\times10^{-3}$	1.6530 $\times10^{-3}$	1.6589 $\times10^{-3}$

Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Not applicable
Calculation method (if applicable):	$\rho_{HC} = (\rho_{NG}-\rho_{CH4} \times CF_{CH4}) / (1-CF_{CH4})$
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	EF_{NG}
Unit:	tCO_2/tNG
Description:	Emission factor of the natural gas
Measured/ Calculated / Default:	Calculated
Source of data:	Information provided by the natural gas supplier
Value(s) of monitored parameter:	The same kinds of natural gas are supplied to the Plant I and Plant II.

Date	2012							Period
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	4
EF_{NG}	2.7587	2.7719	2.7709	2.7711	2.7733	2.7732	2.7754	2.7706

Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Not applicable

Calculation method (if applicable):	$EF_{NG} = COEF_{NG} \times NCV_{NG}/\rho_{NG} \times 44/12$ Where $COEF_{NG}$: Carbon Emission factor of natural gas [tC/TJ] 15.3[tC/TJ] is applied to this project as Ex-ante value by IPCC DEFAULT VALUES OF CARBON CONTENT of "Natural Gas" in TABLE 1.3 (2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2, Energy) NCV_{NG} : Net calorific value of the natural gas [TJ/Nm^3] For this project, NCV_{NG} is offered by KOGAS. ρ_{NG} : Density of the natural gas[t/Nm^3] For this project, based on data source by natural gas supplier.
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	EF_{HC}
Unit:	tCO_2/tHC
Description:	Emission factor of the hydrocarbon with two or more molecular of carbon, which is existed as a contents of the natural gas
Measured/ Calculated / Default:	Calculated
Source of data:	Calculated based on the followings: Methane content offered by the fuel supplier ; The density of the natural gas provided by the fuel supplier ; Estimated emission factor of the natural gas, and Specified methane density
Value(s) of monitored parameter:	The same kinds of natural gas are supplied to the Plant I and Plant II.

Date	2012							Period
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	4
EF_{HC}	2.7977	2.8794	2.8728	2.8748	2.8957	2.8946	2.9094	2.8749

Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Not applicable
Calculation method (if applicable):	$EF_{HC} = (EF_{NG} \times \rho_{NG} - EF_{CH4} \times \rho_{CH4} \times CF_{CH4}) / (1-CF_{CH4}) / \rho_{HC}$ Where EF_{NG} : CO_2 emission factor of NG[tCO_2/tNG ρ_{NG} : Density of natural gas (tNG/m^3) EF_{CH4} : CO_2 emission factor of CH_4(tCO_2/tCH_4). ρ_{CH4} : Density of methane (tCH_4/ m^3). CF_{CH4} : Methane fraction in the natural gas
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	SE_{N2O}
Unit:	kgN_2O/tCaprolactam
Description:	N_2O emission rate per ton of caprolactam
Measured/ Calculated / Default:	Calculated
Source of data:	Baseline and Monitoring Methodology (AM0028 ver05)

Value(s) of monitored parameter:	SE_{N2O} is for this period. $SE_{N2O,period}$(kgN_2O/tCaprolactam): Plant I: 23.00; Plant II: 17.51
Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Not applicable
Calculation method (if applicable):	$SE_{N2O,period} = QI_{N2O,period} / P_{product,period} \times 1000$ Where, $QI_{N2O,period}$ means the monitored quantity of N_2O emissions at the inlet of the destruction facility (t N_2O), and $P_{product,period}$ is the actual output of caprolactam for this period.
QA/QC procedures:	Not applicable
Purpose of data:	Baseline emission Calculation
Additional comment:	Not applicable

Data / Parameter:	$OXID_{CH4}$
Unit:	%
Description:	Oxidation factor of CH_4 in natural gas for re-heating tail gas
Measured/ Calculated / Default:	Calculated
Source of data:	Not applicable
Value(s) of monitored parameter:	Average value in this period $OXID_{CH4}$: Plant I: 96.56; Plant II: 98.27
Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Not applicable
Calculation method (if applicable):	$OXID_{CH4}=\{ Q_{CH4} -(\sum_{i}^{n} F_{TE,i} \times CO_{CH4,i} \times 10^{-6})\} / Q_{CH4} \times 100$
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	CO_{CH4}
Unit:	ppm (v)
Description:	Methane concentration at destruction facility outlet.
Measured/ Calculated / Default:	Measured
Source of data:	Non-dispersion infrared absorption analyzer with dual-channel as a gas path
Value(s) of monitored parameter:	Average value in this period CO_{CH4}: Plant I: 17.08; Plant II: 11.69

Monitoring equipment:	<table><tr><th></th><th>Plant I (CO_{CH4-1})</th><th>Plant II(CO_{CH4-2})</th></tr><tr><td>Type</td><td>NDIR</td><td>NDIR</td></tr><tr><td>Accuracy class</td><td>>95%</td><td>>95%</td></tr><tr><td>Serial No.</td><td>AO-750</td><td>AO-751</td></tr><tr><td>Calibration frequency</td><td>Every 2weeks</td><td>Every 2weeks</td></tr><tr><td>Date of last calibration</td><td>26/12/2012</td><td>26/12/2012</td></tr><tr><td>Validity</td><td>Yes</td><td>Yes</td></tr><tr><td>Model</td><td>ULTRAMAT 6</td><td>ULTRAMAT 6</td></tr></table>
Measuring/ Reading/ Recording frequency:	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Every two years required by the registered PDD, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.
Purpose of data:	Project emission Calculation
Additional comment:	Not applicable

Data / Parameter:	***Reg_{NOx}***
Unit:	tNOX/Nm^3
Description:	National regulation on NOX emissions
Measured/ Calculated / Default:	Not applicable
Source of data:	The "Clean Air Conservation Act", one of the National environmental legislation, Ministry of Environment
Value(s) of monitored parameter:	4.10714 x 10^{-7} tNOx/Nm^3 (as a NO_2 concentration)
Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Recording frequency : Date of Regulation
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Not applicable
Purpose of data:	Baseline emission Calculation
Additional comment:	Not applicable

Data / Parameter:	***$RSE_{N2O,y}$***
Unit:	tN_2O/tCaprolactam
Description:	Regulatory limit of N_2O emissions per unit of outlet of caprolactam (tN_2O/t caprolactam)
Measured/ Calculated / Default:	Not required by national legislation in Republic of Korea.
Source of data:	National legislation in Republic of Korea. (That may be mostly like environmental regulation.)

Value(s) of monitored parameter:	Not applicable
Monitoring equipment:	Not applicable
Measuring/ Reading/ Recording frequency:	Recording frequency : Date of Regulation
Calculation method (if applicable):	Not applicable
QA/QC procedures:	Not applicable
Purpose of data:	Baseline emission Calculation
Additional comment:	Not applicable

D.3. Implementation of sampling plan

>>

Not applicable

SECTION E. Calculation of emission reductions or GHG removals by sinks

E.1. Calculation of baseline emissions or baseline net GHG removals by sinks

>>

In the case of a nitric acid plant or a caprolactam plant using the Raschig process, baseline emissions are limited to the design capacity of the existing nitric acid or caprolactam production plant. If the actual production of caprolactam ($P_{product,actual}$) exceeds the design capacity ($P_{product,max}$), the emissions related to the production above $P_{product,max}$ will not be claimed for the baseline scenario. Therefore $P_{product,\ actual}$ of each plant should be monitored. However, it is not able to be decided whether the actual production of caprolactam exceeds $P_{product,max}$, or not, because those values ($P_{product,max}$ and $P_{product,actual}$) should be compared on the annual values for comparing each other, and only 206 days have been monitored after 1st crediting year, so in order to simply make rough estimation to the status of production, the actual average daily output for this period was compared with the expected average daily output described in PDD, as shown in the Table E.1. (All of the data for the actual daily production of caprolactam were listed in detail in the emission reductions calculation spreadsheet.)

Table E.1-1 The actual value of Caprolactam Production for this period and the expected value of that on PDD

	Yearly expected in PDD			For this period		
	Design Capacity , $P_{product,max}$ (ton/yr)	No. of Operating days In PDD	Daily output (ton/day)	Period total output $P_{product,period}$ (ton/period)	No. of Operating days	Daily output (ton/day)
Plant I	63,307	363	174.40	28,963	206	141
Plant II	64,965	355	183.00	31,879	206	155

Since the last calibration of the equipment for monitoring the caprolactam production of the Plant II was delayed and the results of the error of the delayed calibration is smaller than the maximum permissible error ±0.15%, the maximum permissible error of this equipment shall be applied to the measured values taken during the period between 07/10/2012 and 15/10/2012 as per the para 238(a) VVS. If the maximum permissible error of this equipment is applied to the daily $P_{product-2}$ from 07/10/2012 to 15/10/2012, the daily $P_{product-2}$ is below the designed capacity (183.00 ton/day), as follows:

Table E.1-1-1 The comparison results of the daily $P_{product-2}$ to its designed capacity applying the maximum permissible error +0.15% to the measured values

Date	Measured $P_{product-2}$ (ton/day)	Apply the maximum permissible error (+0.15%) (ton/day)	result (ton/day)
07/10/2012	176.20	176.46	<183.00
08/10/2012	176.69	176.96	
09/10/2013	175.59	175.85	
10/10/2013	175.77	176.03	
11/10/2014	14.70	14.72	
12/10/2014	0.00	0.00	
13/10/2015	0.00	0.00	
14/10/2015	0.00	0.00	
15/10/2016	0.00	0.00	
Total	718.95	720.03	+1.08

As a result, it can be said that actual production of caprolactam ($P_{product}$) did not exceed the design capacity ($P_{product,max}$). Therefore on the condition of $P_{product,y} < P_{product,\ max}$, baseline emissions (*BE*) for the period are given by following equation :

$$BE_{\ period,\ within\ permit\ range} = \left(\sum_{i}^{n} F_{TI,i} \times CI_{N2O,i} \times M_i\right) \times GWP_{N2O}$$

Where

M_i	Length of Measuring Interval (hr), (1hr : set value at instrument for this project)
GWP_{N2O}	Global warming potential of the N_2O, (310: default value).
n	Number of intervals during this period
$F_{TI,i}$	Volume flow rate at the inlet of the DF during interval (Nm^3/hr)
$CI_{N2O,i}$	N_2O concentration in the tail gas of the DF inlet during interval (tN_2O/ Nm^3)

However, if the actual average daily operating temperature and/or pressure in the ammonia oxidation reactor (T_g and P_g) are outside the bounds of the "permitted range" of AOR operation conditions (: $T_{g,hist}$ and/or $P_{g,hist}$), the calculation of baseline emission is the integration of the daily baseline emission($BE_{,daily,\ out\ of\ permit\ range}$) for the respective day. The daily baseline emission is calculated for the respective time period as follows:

$$BE_{daily,\ out\ of\ permit\ range} = P_{product,\ day} \times EF_{N2O} \times GWP_{N2O} / 1000$$

$$BE_{period,\ out\ of\ permit\ range} = \sum BE_{daily,\ out\ of\ permit\ range}$$

Where

$BE_{daily,\ out\ of\ permit\ range}$	: The daily baseline emission for the respective day in which AOR operation conditions were outside of "permitted range"($tonCO_2$/day)
$P_{product,\ day}$	: The daily output of caprolactam for the respective day in which AOR operation conditions were outside of permitted range (ton caprolactam/day)
EF_{N2O}	: N_2O Emission factor to the process of caprolactam production (kgN_2O/ton caprolactam)

Emission factor of N_2O(EF_{N2O}) is the lowest value among (a) $EF_{N2O,IPCC}$, (b) $SE_{N2O,y}$ and (c) any related value as a result of legal regulation(e.g. $RSE_{N2O,y}$). In Republic of Korea, there is no mandatory regulation for N_2O emission. Therefore, actually EF_{N2O} is the lower value between (a) $EF_{N2O,IPCC}$ and (b) $SE_{N2O,y}$.
$F_{N2O,IPCC}$ means Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N_2O emission process. At this time, $EF_{N2O,IPCC}$ is 5.4kgN_2O/tonne of caprolactam.

$SE_{N2O,y}$ is the specific N_2O emission per unit of output of caprolactam defined as :

$$SE_{N2O,y} = QI_{N2O,y} / P_{product,y} \times 1000$$

Where, $QI_{N2O,y}$ means Quantity of N_2O emissions at the inlet of the destruction facility in year, y given by :

$$QI_{N2O,y} = \sum_{i}^{n} F_{TI,i} \times CI_{N2O,i} \times M_i$$

For this period, $SE_{N2O,y}$ and $QI_{N2O,y}$ should be converted as $SE_{N2O,period}$ and $QI_{N2O,period}$ as follows :

$$SE_{N2O,period} = QI_{N2O,period} / P_{product,period}$$

The both of $SE_{N2O,y}$ values for plants are calculated as higher than $EF_{N2O,IPCC}$ (23.00 for plant 1 and 17.51 for plant 2), and thus the values of EF_{N2O} are decided as 5.4kgN_2O/tonne of caprolactam in order to calculate $BE_{period,\ out\ of\ permit\ range}$.

Table E1-2 $SE_{N2O,y}$ for this period (period 4)

		Plant 1	Plant 2
$QI_{N2O\ -Plant1}$	ton N_2O/period	666.18	558.28
$P_{product\ -Plant1}$	ton Caprolactam/yr	28,963	31,879
$SE_{N2O,period}$	kgN_2O/tCaprolactam	23.00	17.51

If the actual daily ammonia flow rate exceeds the (upper) limit on maximum historical daily permitted ammonia flow rate, the baseline N_2O emissions for this operating day are capped at conservative IPCC default values. Where, the upper limit on ammonia flow should be determined based on "the historical

operating data on maximum daily average ammonia flow".

Consequently, on condition of $P_{product,\,y} < P_{product,\,max}$, baseline emissions (*BE*) for the period can be calculated as follows for this period.

$$BE_{period} = BE_{period,\,within\ permit\ range} + BE_{period,\,out\ of\ permit\ range}$$

(a) Baseline emission of Plant 1

In Case of AOR operation conditions within "permitted range"

In order to calculate the hourly BE ($BE_{,hr-1}$), the hourly integrated measured values of $F_{TI,i\ -1}$and $CI_{N2O,-1}$ except the data to the day in which AOR was operated outside of permit range, are input. These hourly BE ($BE_{,hr-1}$) are aggregated to the daily BE($BE_{,day}$), and total BE on this period for plant I ($BE_{,period-1}$), 205,334.77 tonCO_2/period. BE calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

In case of AOR operation conditions outside of "permitted range"

For this period, the number of days on which the conditions of AOR deviated from permitted range is 17. (Refer to Table B.1). Among them, 16 days showed zero values of caprolactam products, except one day. The baseline emission calculation for period 4 depending on following equation.

$$BE_{period,\,out\ of\ permit\ range} = \sum BE_{daily,\,out\ of\ permit\ range} = P_{product,\,day} \times SE_{N2O,period} \times GWP_{N2O} / 1000$$

Table E.1-3 The date and *BE* on the condition of AOR deviated from permitted range in Plant 1

	Date (dd/mm/yyyy)	Product (ton/day)	$BE_{daily,\,out\ of\ permit\ range}$ (ton CO_2/day)
1	06/07/2012	0.00	0.00
2	10/07/2012	0.00	0.00
3	11/07/2012	0.00	0.00
4	12/07/2012	0.00	0.00
5	13/07/2012	0.00	0.00
6	24/07/2012	152.03	254.50
7	12/10/2012	0.00	0.00
8	13/07/2012	0.00	0.00
9	14/07/2012	0.00	0.00
10	15/07/2012	0.00	0.00
11	16/07/2012	0.00	0.00
12	17/07/2012	0.00	0.00
13	18/07/2012	0.00	0.00
14	19/07/2012	0.00	0.00
15	20/07/2012	0.00	0.00
16	21/07/2012	0.00	0.00
17	23/10/2012	0.00	0.00
		$BE_{period,\,out\ of\ permit\ range}$ (ton CO_2/period)	254.50

The baseline emission in which AOR operation conditions were outside of permitted range for this period ($BE_{period,\,out\ of\ permit\ range}$) is 254.50

(b) Baseline emission of Plant II

In Case of AOR operation conditions within "permitted range"

Hourly BE ($BE_{,hr-2}$) calculated on hourly integrated measured values of $F_{T\,i-2}$ and $CI_{N2O,i-2}$ are aggregated to the daily BE($BE_{,day-2}$), and total BE on the period ($BE_{,period-2}$) are estimate as sum of $BE_{,day-2}$. The total BE on

the period 4 for Plant 2 ($BE_{,period-2}$) is 171,922.08tonCO_2/period. BE calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

In case of AOR operation conditions outside of "permitted range".

For this period, the number of days on which the conditions of AOR deviated from permitted range is 19. (Refer to Table B.1). Among them, 17 days showed zero values of caprolactam products, except two day. The baseline emission calculation for period 4 depending on following equation.

$$BE_{period,\ out\ of\ permit\ range} = \sum BE_{daily,\ out\ of\ permit\ range} = P_{product,\ day} \times SE_{N2O,period} \times GWP_{N2O} / 1000$$

The last calibration of the equipment for monitoring the caprolactam production of the Plant II was delayed and the results of the error of the delayed calibration is smaller than the maximum permissible error ±0.15%. For conservative purpose, the maximum permissible error (-0.15%) of this equipment shall be applied to the measured values taken during the period between 07/10/2012 and 15/10/2012 as per the para 238(a) VVS.

Table .E1-4 The date and *BE* on the condition of AOR deviated from permitted range in Plant 2

	Date (dd/mm/yyyy)	Measured Production (ton/day)	Measured Production applying maximum error (-0.15%) (ton/day)	$BE_{daily,\ out\ of\ permit\ range}$ (ton CO_2/day)
1	10/10/2012	175.77	175.51	293.80
2	11/10/2012	14.70	14.68	24.57
3	12/10/2012	0.00	0.00	0.00
4	13/10/2012	0.00	0.00	0.00
5	14/10/2012	0.00	0.00	0.00
6	15/10/2012	0.00	0.00	0.00
	Date (dd/mm/yyyy)	Product (ton/day)		$BE_{daily,\ out\ of\ permit\ range}$ (ton CO_2/day)
7	16/10/2012	0.00		0.00
8	17/10/2012	0.00		0.00
9	18/10/2012	0.00		0.00
10	19/10/2012	0.00		0.00
11	20/10/2012	0.00		0.00
12	21/10/2012	0.00		0.00
13	22/10/2012	0.00		0.00
14	23/10/2012	0.00		0.00
15	24/10/2012	0.00		0.00
16	25/10/2012	0.00		0.00
17	26/10/2012	0.00		0.00
18	27/10/2012	0.00		0.00
19	28/10/2012	0.00		0.00
		$BE_{period,\ out\ of\ permit\ range}$ (ton CO_2/period)		318.37

(c) The total BE of Period 4

Eventually, Total BE in this period is about 377,829.72 tonCO_2 /period as shown below table.

Table E1-5 Summary of BE for this period

		$BE_{period-4}$ (ton CO_2/period)	
		$BE_{period-4}$ in Plant I	$BE_{period-4}$ in Plant II
BE_{period} on AOR condition	within "permitted range	205,334.77	171,922.08
	Outside "permitted range	254.50	318.37
BE_{period} total	BE_{period} for each plant	205,589.27	172,240.45
	$BE_{period-total}$	377,829.72	

E.2. Calculation of project emissions or actual net GHG removals by sinks

>>

The emission due to the project activity are composed of (a) the emissions of not destroyed N_2O, (b) on-site emissions due to the hydrocarbons (; Natural Gas) use as input to the N2O destruction facility, and (c) the emissions from the operation of the destruction facility. Hydrocarbons can be used as reducing agent and/or re-heating the tail gas to enhance the catalytic N_2O reduction efficiency. In this project, natural gas is used for re-heating the tail gas to enhance the catalytic N_2O reduction efficiency.

$$PE_{period} = \left(\sum_{i}^{n} F_{TE,i} \times CO_{N2O,i} \times M_i\right) \times GWP_{N2O}$$
$$+ \left[(\rho_{HC} \times Q_{HC,y} \times EF_{HC} \times OXID_{HC}/100) + (\rho_{CH4} \times Q_{CH4,y} \times EF_{CH4} \times OXID_{CH4}/100)\right]$$
$$+ \left[\rho_{CH4} \times Q_{CH4,y} \times GWP_{CH4} \times (1-OXID_{CH4}/100)\right]$$

n	: Number of intervals during the year (period^{-1})
M_i	: Length of Measuring Interval (hr), (1hr : set value at instrument for this project)
$F_{TE,i}$	: Volume flow rate at the exit of the DF during interval i (Nm^3/hr)
$CO_{N2O,i}$	: N_2O concentration in the tail gas of the DF exit during interval i (tN_2O/m^3)
GWP_{CH4}	: Global warming potential of CH_4, 21 (: default value)
GWP_{N2O}	: Global warming potential of the nitrous oxide, 310 (: default value)
ρ_{CH4}	: Density of methane (tCH_4/m^3) , 0.000716
ρ_{HC}	: Density of HC (tHC/m^3)
EF_{CH4}	: CO_2 emission factor of CH_4 (tCO_2e/tCH_4), 2.75
EF_{HC}	: CO_2 emission factor of HC with two or more carbon molecule in natural gas (tCO_2e/tHC)
$Q_{CH4,y}$	: Methane used in period (Nm^3/period)
$Q_{HC,y}$	: HC with two or more carbon molecule in natural gas used in period (Nm^3/period)
$OXID_{CH4}$	: Oxidation factor of methane (%)
$OXID_{HC}$	: Oxidation factor of HC(%), 100% (Fixed value)

Hourly calculated PE ($PE_{,hr}$) are aggregated into the daily PE($PE_{,day}$), and total PE on the period ($PE_{,period}$) are estimated as sum of $PE_{,day}$. ER calculation sheet for each plant which daily measured and calculated results were integrated into is in detail on the mission reductions calculation spreadsheet.

(a) <u>Project emission of Plant I</u>

In order to calculate the hourly PE ($PE_{,hr-1}$) for Plant I, the hourly integrated measured values of $F_{TE,i-1}$and $CO_{N2O,i-I}$ are input. These hourly PE ($PE_{,hr-1}$) are aggregated to the daily PE($PE_{,day-1}$). The total PE on the period3 for plant I ($PE_{,period-1}$) is 26,229.66tonCO_2/period . PE on this period for plant I calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

(b) <u>Project emission of Plant II</u>

The hourly integrated measured values of $F_{TE,i-2}$ and $CO_{N2O,i-2}$ are input for calculating hourly PE for Plant II($PE_{,hr-2}$) , and then these hourly PE ($PE_{,hr-2}$) are aggregated to the daily PE($PE_{,day-2}$). The total PE on this period for plant II ($PE_{,period-2}$) is 21,018.33 tonCO_2/period. PE on the period3 for plant II calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

(c) <u>The total PE of Period 4</u>

Total PE in this period is 47,248.00 ton CO_2 as shown below table.

Table E.2-1 Summary of PE for this period

	Plant I	Plant II
PE for each Plant (ton CO_2/period)	26,229.66	21018.33

PE for Period total, $PE_{period-4}$ (ton CO_2/period)	47,248.00

E.3. Calculation of leakage

>>

The installation of the N_2O destruction facility doesn't result in significant additional energy consumption at the caprolactam production plant. In conclusion, no leakage is expected at this project as per the registered PDD. The emission by leakage is accounted as zero ($LE_y = 0$)

E.4. Summary of calculation of emission reductions or net anthropogenic GHG removals by sinks

The emission reduction ER_{period} by the project activity during a given year *y* is the difference between the baseline emissions (BE_{period}) and project emissions (PE_{period}), as follows:

$$ER_{period} = BE_{period} - PE_{period} - LE_{period}$$

Therefore ER_{period} can be estimated upon the values of BE_{period} PE_{period} and LE_{period} those are calculated as mentioned above.

Table E.4 Summary of calculation of emission reductions

Item	Baseline emissions or baseline net GHG removals by sinks (t CO_2e)	Project emissions or actual net GHG removals by sinks (t CO_2e)	Leakage (t CO_2e)	Emission reductions or net anthropogenic GHG removals by sinks (t CO_2e)
Plant I	205,589.27	26,229.66	0	179,359.60
Plant II	172,240.45	21,018.33	0	151,222.12
Period Total	377,829.72	47,248.00	0	330,581

E.5. Comparison of actual emission reductions or net anthropogenic GHG removals by sinks with estimates in registered PDD

Below table is to show comparison of actual values of the emission reductions achieved during the monitoring period with the estimations in the registered CDM-PDD.

Item	Values estimated in ex-ante calculation of registered PDD	Actual values achieved during this monitoring period
Emission reductions or GHG removals by sinks (t CO_2e)	373,054	330,581

As a conclusion, The actual emission reduction during this monitoring period is lower than the ex-ante value of the registered CDM-PDD.

E.6. Remarks on difference from estimated value in registered PDD

>>

Not applicable

E.7 Actual emission reductions or net anthropogenic GHG removals by sinks during the first commitment period and the period from 1 January 2013 onwards

Item	Actual values achieved up to 31 December 2012	Actual values achieved from 1 January 2013 onwards
Emission reductions or GHG removals by sinks (t CO_2e)	330,581	Not applicable

Table E.7 Actual ER during first commitment period tonCO_2eq.

Implemented monitoring period		no. of days	Plant I	Plant II	Plant total
period 1	09/06/2011–31/08/2011	84	83,658	61,093	144,751
period 2	01/09/2011 – 31/12/2011	122	117,730	98,808	216,538
Period 3	01/01/2012 – 08/06/2012	160	172,493	144,743	317,236
period 4	09/06/2012 – 31/12/2012	206	179,360	151,222	330,581
total	**09/06/2011-31/12/2012**	**572**	553,241	455,866	1,009,106

- - - - -

Document information

Version	*Date*	*Description*
03.2	5 November 2013	Editorial revision to correct table in page 1.
03.1	2 January 2013	Editorial revision to correct table in section E.5.
03.0	3 December 2012	Revision required to introduce a provision on reporting actual emission reductions or net anthropogenic GHG removals by sinks for the period up to 31 December 2012 and the period from 1 January 2013 onwards (EB70, Annex 11).
02.0	13 March 2012	Revision required to ensure consistency with the "Guidelines for completing the monitoring report form" (EB 66, Annex 20).
01	28 May 2010	EB 54, Annex 34. Initial adoption.

Decision Class: Regulatory
Document Type: Form
Business Function: issuance
Keywords: monitoring report, performance monitoring